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JOURNAL OF THE ROYAL SOCIETY OF ARTS

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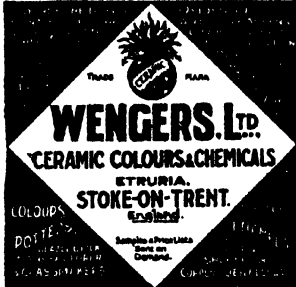
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JOURNAL OF THE ROYAL SOCIETY OF ARTS

No. 3885.

VOL. LXXV.

FRIDAY, MAY 6th, 1927.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2.)

NOTICES.

NEXT WEEK.

MONDAY, MAY 9th, at 8 p.m. (Cantor Lecture.) JOHN W. T. WALSH, M.A., M.Sc., F.Inst.P., A.M.I.E.E., Senior Assistant, National Physical Laboratory, and General Secretary, International Commission on Illumination, "The Measurement of Light." (Lecture III.)

The Lecture will be illustrated by experimental demonstrations.

WEDNESDAY, MAY 11th, at 8 p.m. (Ordinary Meeting.) PROFESSOR WILLIAM ERNEST DALBY, M.A., F.R.S., M.Inst.C.E., Dean of the City and Guilds Engineering College, Imperial College of Science and Technology "English Railways." (Dr. Mann Lecture.) BRIGADIER-GENERAL SIR BRODIE H. HENDERSON, K.C.M.G., C.B., M.Inst.C.E., will preside.

This is the second and concluding lecture by Professor Dalby on this subject, the first lecture having been delivered on May 4th.

EIGHTEENTH ORDINARY MEETING.

WEDNESDAY, APRIL 27TH, 1927. REAR-ADMIRAL JAMES DE COURCY HAMILTON M.V.O. in the Chair.

The following candidates were proposed for election as Fellows of the Society :

Clark, Norman G., Melbourne, Australia.

Connell, W. H., London.

Cullinan, Joseph S., Houston, Texas, U.S.A.

Dass, Janaki Nath, B.A., Ingabu, Lower Burma.

Enright, Robert John Patrick, Pallavaram, South India.

Foss, Feodore F., Wheeling, Virginia, U.S.A.

Harris, Major-General George Francis Angelo, C.S.I., M.D., F.R.C.P., London.

Hart, Charles, Chester, Pa., U.S.A.

Order, P. Morley, F.S.A., London.

Nawn, High, Boston, Mass., U.S.A.

Pratt, Arthur, Johannesburg, South Africa.

Takeda, Admiral Hideo, I.J.N. (retd.), Tokyo, Japan.

Toll, Pelham E. S., Hove, Sussex.

Whittier, Charles E., Chicago, Illinois, U.S.A.

Wright, James Alpheus, Montreal, Canada.

The following candidates were duly elected Fellows of the Society :

Beale, Sir John Field, K.B.E., London.

Kenrick, John P., Peking, China.

Shear, Professor T. Leslie, A.M., Ph.D., Princeton, New Jersey, U.S.A.

A paper on " Fire Waste (Loss of Property by Fire) and its Effects on the Economics of National Life in Great Britain " (Fothergill Prize Essay) was read by Mr. G. E. KEAY of the Norwich Union Fire Insurance Society Ltd.

The paper and discussion will be published in the *Journal* dated June 24th.

CANTOR LECTURE.

MONDAY, MAY 2nd, 1927. MR. JOHN W. T. WALSH M.A. M.Sc., F.Inst.P., A.M.I.E.E., Senior Assistant, National Physical Laboratory, and General Secretary, International Commission on Illumination, delivered the second of his course of three lectures, illustrated by experimental demonstrations, on "The Measurement of Light."

The lectures will be published in the *Journal* during the summer recess.

BINDING COVERS FOR JOURNALS.

For the convenience of Fellows and others wishing to bind their annual volumes of the *Journal*, cloth covers can be supplied, post free, for 2s. each, on application to the Secretary.

PROCEEDINGS OF THE SOCIETY.

FOURTEENTH ORDINARY MEETING.

WEDNESDAY, MARCH 9TH, 1927.

DR. ARTHUR SMITHELLS, C.M.G., D.Sc., F.R.S., in the Chair.

The CHAIRMAN said that the subject of coke had in recent times become of greatly increased interest and importance. There was a strong public demand for information, and it was very desirable that the demand should be granted, and that the information should be authoritative. In the position which Dr. Smith occupied as Technical Director of the Woodall-Duckham Companies, and in many other ways, he was in the heart of the fuel world and knew all that was going on. He could promise them with great confidence an interesting and valuable address.

The following paper was then read:—

THE UTILISATION OF GAS COKE.*

By E. W. SMITH, D. Sc., F.I.C.

Technical Director, Woodall-Duckham Companies.

It is desired that I should explore the subject of the utilisation of gasworks coke.

Commercially, there is only one other type of coke available, and that is made at coke ovens, and used largely in metallurgical operations. Each is a product of the distillation of bituminous coking coals, although in recent years it has been shown that by correctly blending non-coking coals with coking coals good coke may be made. Coke oven coke is usually denser, harder, less combustible, lower in ash and moisture than gas cokes. It is the main product of the coking industry, while gas coke has been what is known as a residual, though by far the most important residual. Six shillings a ton difference in the selling price of coke will affect the selling price of gas by about a halfpenny a therm.

During the last two years, we have had presented to us a large number of technical contributions on the subject of coke—its formation, its combustibility, its reactivity, grading, quenching, and so on—but there is still a lot to learn. This technical activity has been stimulated largely through two or three causes—the public desire for smoke abatement—the activities of those engaged in the development of processes of low temperature carbonisation, and because of the non-success of the latter commercially, an attempt on the part of those engaged in the well established high temperature carbonisation industries so to improve the coke residue as to provide a solid smokeless fuel.

Such technical contributions have laid the foundations for progressive technical development, and already a great change is taking place in many gas undertakings.

Attempts are being made to carbonise a greater proportion of low ash or cleaner coals. More collieries are consequently installing coal cleaning plants, and in one case—Glasgow—a gas undertaking is itself arranging to clean its coals. In all such cases lower ash coke will be available. Then methods of coke quenching in many cases are given more attention where static methods of carbonisation are used, and with the enormous growth of continuous vertical retort practice, dry coke from such plants may be assured.

Coke screening and grading—for its different uses—is becoming quite common, and last, but by no means least, the apparatus of all kinds in which coke is burnt is being modified and improved.

The possibilities of such progressive development are observable in those large cities that have taken advantage of recent developments, when it is

* The paper was illustrated by a number of lantern slides shewing various types of apparatus for burning coke.

realised that the demands for the improved coke are so great that in some cases there is an actual shortage.

The time may not be very distant when coke will take its place on an equal footing with gas in the economics of gas undertakings, and whilst periodic fluctuations in the coke demands can be taken care of by stocking, the seasonal fluctuations of gas not taken care of by the holders, can be used for heating the carbonising plants.

The coal carbonised in gasworks is approximately 18,000,000-tons per annum, and the total coke made, including breeze, is nearly 12,000,000-tons.

This is disposed of approximately as follows :—

Coke used on producers for heating retorts	...	...	3,282,748-tons.
Coke used for water gas manufacture	...	...	1,153,413 "
Coke for export	...	...	889,281 "
Coke for home consumption	...	...	6,507,400 "
			11,832,842-tons.

Of the 6½ million tons of coke available for home consumption, probably 700,000 tons represent the weight of coke breeze, and fines, and the remainder represents the amount available, when sized and graded for its varied applications, or domestic and industrial uses.

The amount of *coal* used for domestic purposes is about 40 million tons.

There is a large amount of technical coke development work being carried out for the Gas Industry. Contributions have already been made by different members of the staffs of Leeds and Sheffield Universities. The Birmingham Gas Department, The Gas Light & Coke Company, the South Metropolitan Gas Company, and the Newcastle Gas Company are each carrying out important technical work in this direction, and no doubt there are many others.

It is not my purpose—nor have I the time this evening—to explore the technique of the coke question, but I wish rather to attempt to give you a comprehensive survey of the uses to which coke is put—a survey of a type which, I hope, has not so far been made in this particular way.

In Fig. 1. you will find a list of the various uses for which one large provincial gas undertaking sells its make of coke. This undertaking has found it advisable, in order to meet the demands of the market, to screen the coke into five sizes—above 2in. ; 2in. to 1½in. ; 1½in. to 11/16in. ; 11/16in. to ¾in. ; and below ¾in. The coke is, in addition, supplied in as dry a state as possible.

DOMESTIC USES OF COKE.

The heating of rooms, and the supply of hot water, enter into the domestic economy of all households in this country, and I need make no apology for treating this subject at some length. Whilst the heating of rooms may be carried out independently of the supply of hot water, it is generally found con-

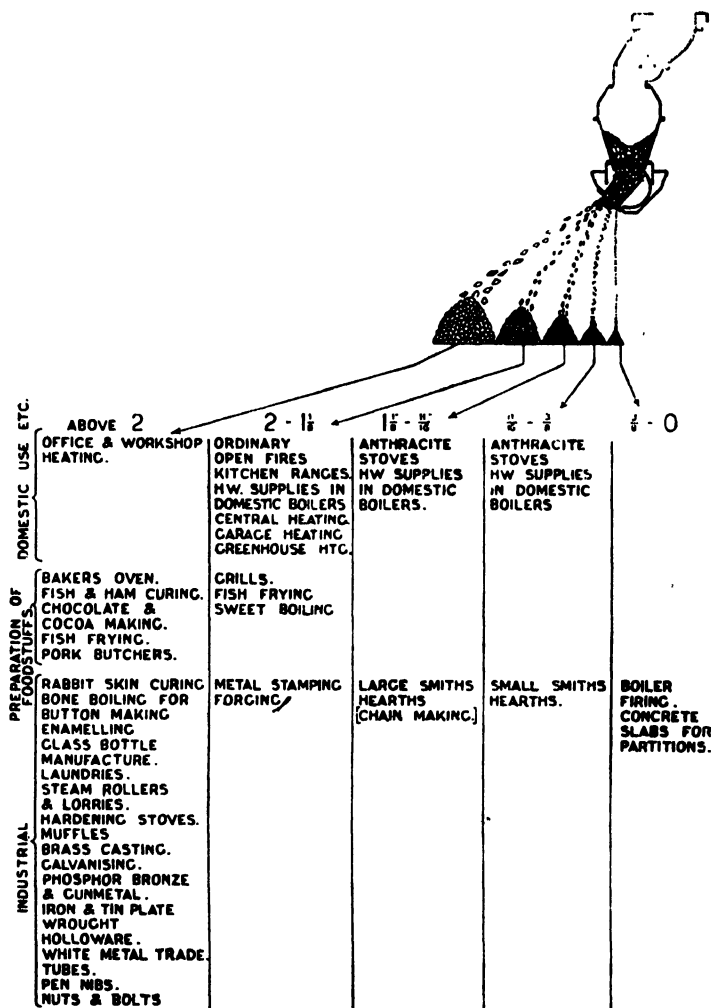


FIG. 1.—The uses of gas coke.

venient and economic to carry out the two operations by the same apparatus. We are all familiar with the open grate fitted at the back with a hot water boiler, and it is necessary to review the methods and apparatus by which gas coke is utilised for room heating alone, and for heating rooms in combination with water heating.

THE OPEN GRATE AND ITS MODIFICATIONS.

The increasing price of coal of recent years has led to the substitution, in many instances, of the old-fashioned open grate, with its abundance of iron bars, side and back plates, and its excessive air supply, by the slower burning

semi-well and well grates. The back and sides of this type of grate are invariably of firebrick, and the front bars are absent. Gas coke, providing it is reasonably dry, and sized between 2in. and 1½in., may be burnt in any such grate which burns coal successfully. An illustration of an ordinary semi-well grate burning gas coke of this size is given in Fig. 2. The grate is 16in. wide

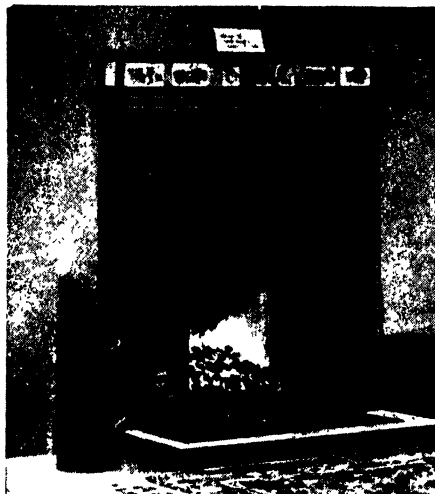


FIG. 2.—Standard open fire burning gas coke.

at the front, and is 11ins. deep from front to back. The coke may be ignited by paper and wood in the ordinary way, or by using a gas jet. Thereafter, all that is required is to keep the fire replenished, throwing the fresh coke to the back of the fire. It is desirable that the fire should not be allowed to burn too low before replenishing. Dry gas coke graded to between 2in. and 1½in. will keep an ordinary sized room (say 12ft. x 14ft.) warm when burning at the rate of about 2lbs. per hour, which, with coke at 40/- per ton, is equivalent to a cost of about ½d. per hour.

In this way coke may be substituted for coal, in many instances with no structural alterations, the amenities of the open fire being retained. There is still a very great number of instances where the utilisation of gas coke may be extended in this manner, the chief obstacle in far too many cases, it must be admitted, being the difficulty of obtaining a dry coke suitably graded.

Progress is being made in the perfecting of fires of the open grate type specially designed for the burning of gas coke. The chief amongst these are the Hodsman Fire, "Glow-Worm" open coke fire (Dr. Owen's patent) the "Rayflex" open coke fire (Dr. Weyman's patent), the N.C. fire (Mr. Nichol's patent), the new fire developed by the South Metropolitan Gas Company.

In the "Glow-Worm" open coke fire (Fig. 3), the coke is held in the form of a vertical layer between widely spaced bars at the front, and closely spaced bars at the

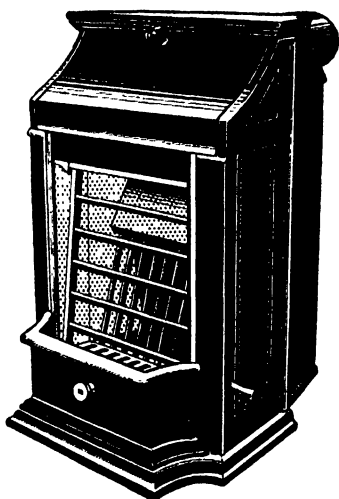


FIG. 3.—“Glow-worm” open coke fire.

bottom and back. The fuel is fed through the canopy which is hinged, and opens for this purpose. The ashpan acts as a damper, and when starting from cold it is pushed right back, the air for combustion being drawn through the front bars, through the fuel bed and up the back flue to the chimney. Under this condition, the whole of the chimney pull is utilised in drawing air through the fuel bed, and the fuel bed increases in temperature at a very rapid rate. To continue to drive the fire in this way at the full rate would lead to an unnecessary wastage of fuel. By drawing forward the ashpan, the direction of the air current may be progressively diverted from the horizontal from front to back to the vertical from bottom to top, and the rate at which the fuel burns reduced.

Thus, after the fire has attained a useful temperature by means of the full draught, a position of the ashpan may be found which is just sufficient to maintain the fuel at that temperature. To preserve the ventilating effect of the ordinary open fire, an auxiliary opening underneath the canopy allows air to be drawn into the chimney by the injecting action of the hot products of combustion, and thus the air of the room is changed sufficiently often to preserve its freshness. In the latest models, a control plate is fixed in this duct, so that the ventilating effect may be obtained without the persons in the room feeling “draughts.” The fire is self-contained, and may be fitted in any existing open grate; it may also be built in the ordinary register, and tiled surround, during the construction of new houses. I am attracted by this type of fire as it permits of regulation of the heat thrown out into the room almost to the same degree as is obtained with a gas fire.

A still more recent development of the “Glow-Worm” open coke fire is the provision at the back of a boiler for heating the necessary domestic supply of hot

water. The boiler is placed immediately behind the back bars, and thus the coke does not come into actual contact with the boiler. The coke may therefore attain a temperature greatly in excess of that of the boiler, and permit of any carbon monoxide formed being completely burnt.

Coke of from 1 in. to $1\frac{1}{2}$ in. is recommended for use in this fire, though the smaller sizes—bean breeze, etc., may be used. The small fire, when driven to the full, is stated to consume 2 lbs. of coke per hour, and when running at the normal rate, $1\frac{1}{4}$ lbs. per hour.

In the "Rayflex" fire, the fuel is supported on inclined fire bars with a practically closed front. The air for combustion is drawn through the top of the fire and downwards through the firebars, and up the back of the fire to the chimney. If desired, a boiler may be placed behind the firebars. The rate of combustion is under control by means of air slides, the ash box under the firebars, and by a damper at the top of the back flue.

Behind the canopy and above the fire, is a perforated plate which permits an amount of air to be drawn directly into the chimney for ventilating the room. The heat passes into the room from two sources.

(a) By direct radiation from the surface of the fire, and

(b) By convection from the front plate and the canopy.

In lighting this fire with paper and wood, the process used is the reverse from that adopted with the ordinary open grate. Coke is first placed on the firebars, then the wood, and then pieces of lighted newspaper are thrown on the wood. As soon as the wood is well alight, more coke is piled on the wood. In a very short time the zone of combustion, which travels upwards to the source of the air, i.e. the surface of the coke, is radiating heat into the room, and thereafter the only attention required is a slight disturbing of the fuel with the poker, and the addition of fresh fuel.

It is calculated that 55 per cent. of the heat in the coke passes into the room by radiation, and 17 per cent. by convection. There is no carbon monoxide in the waste gases. The size of gas coke recommended is $\frac{1}{2}$ in. to 1 in., but other grades varying somewhat from this, may be used. The coke consumption of the grate illustrated is stated to be about 2 lbs. per hour over the day's run.

The "N.C." Fire is a simple modification of the ordinary open grate. It is in essence an open fire grate, the firebrick back and sides of which are made with a series of deep vertical grooves extending from the hearth level to a point above the normal level of the fuel in the grate. These channels act as miniature chimneys, inducing convection currents of air inwards through the fuel bed from the front to the back of the grate. Control is through opening or closing the fret in the ashpan cover, opening if the rate of combustion is to be reduced, and closing if to be increased. This grate, by removing the front bars, is converted into an ordinary semi-well grate, and is then suitable for use with coal or a mixture of coal and coke.

SLOW COMBUSTION STOVES.

Unless attention is given every two or three hours or so to the open fire and its modifications already dealt with, the fire will die out. I would direct your attention now to the slow combustion type of stove which will burn continuously, if large enough, night and day. This class of stove is essentially useful for rooms where continuous warmth with a minimum of attention to the fire is required. Amongst the several makes of slow combustion stoves, the "Esse" and "E.M.J." may be mentioned. In both makes the coke bed is entirely enclosed in a cast iron body, and rests on a bar grate which may be agitated to allow the particles of ash to drop into the ash box. An outlet flue fitted with a controlling damper is situated at the back and leads the products of combustion into the ordinary chimney or a flue leading to the outside of the building. The ash box underneath the grate is closed by a door in which is fitted an air regulator. The fuel is fed into the stove through a door at the top, and sufficient fuel may be charged at once for several hours consumption. A special feature of the E.M.J. stove is the provision of ventilation tubes at the back of the fire. These tubes permit air to be drawn directly into the chimney without passing through the fire, and thus a greater volume of air is drawn through the room than that just required to keep the fire burning. A similar effect is obtained by a special damper fitted to the "Esse" stove. Gas coke graded preferably 1½ in. to 11/16 in. is recommended, though smaller fuel, say ¾ in. to ½ in. can also be used. The average coke consumption may be taken as about 1 lb. per hour, which at 40/- per ton is equivalent to about a *farthing an hour*. The only attention required is daily removal of the ash which is effected by shaking the grate and then withdrawing the ash box. Two, or at most three, fillings of coke per 24 hours are required.

These stoves heat the room mainly by warming the air in immediate contact with the metal of the stove. The warm air commences to rise and a regular system of "convection" currents is set up which ultimately provides warmth in all parts of the room. A small amount of heat passes into the room by radiation. Such stoves are made in sizes suitable for heating rooms from 1,500 to 17,000 cu. ft. in volume.

I would now draw your attention to a large capacity warm air circulator—the "Minerva." The standard sizes are suitable for heating from 30,000 to 200,000 cu. ft. of air space. It consists of an inner cast iron chamber containing the coke bed, which is supported on firebars. The outside casing is of metal, and in between the outer casing and the combustion chamber is an inner casing of insulating material. The top of the combustion chamber leads to the flue pipe in which is situated a damper. The firing door is situated at the front about 15 ins. above the firebars. The ash door is provided with a clamp with a removable handle, so that it can never unwittingly be left open and cause damage to the combustion chamber by too high a fuel bed temperature. The

air supply to the fire is admitted through a controlled air port in the ash door. A simple control handle operates by chains the air port and flue damper. The air to be warmed enters the circulator in the outer ring of the top grating and passes down between the outer casing and the inner insulating casing. This serves to keep the outer casing quite cool. The air then ascends in contact with the outside of the combustion chamber and is discharged through the centre of the grating or into a duct if the circulator is outside the room to be heated. At the bottom of the circulator the air passes over water troughs, which may, if required, contain antiseptics.

The smallest size consumes 2lbs. of coke per hour, and discharges 10,000 cu. ft. of air at 250° F. per hour. This model is suitable for residences and clubs. The largest size discharges 50,000 cu. ft. and consumes 7lbs. per hour, and is suitable for workshops, warehouses, etc. This latter type, if placed in a suitable position, can warm the whole of a large building. A further application of this warm air circulator is in supplying air to drying rooms in the manufacture of soap, in laundries, baths, etc.

HOT WATER FOR DOMESTIC PURPOSES AND HEATING OF ROOMS.

There are many forms of apparatus in which coke is used for the production of hot water for domestic purposes and for heating by hot water radiators. These boilers are very suitable for installing in ordinary houses in place of, or as an adjunct to, the kitchen range. In this type of coke boiler of which the "Glow Worm" and "Ideal" are typical the coke bed is surrounded by a water jacket to which it imparts the greater proportion of its heat. The air for combustion enters through an air inlet in the ash pan door, and the products of combustion escape through a flue at the back upper corner, which is fitted with a control damper. There is a front door which may be opened to permit a certain amount of the heat in the fuel bed to be passed into the room by radiation. The water jacket is supplied with flow and return pipes which are connected to the ordinary hot water supply pipes of the house. The larger sizes of boilers have a sufficient heating surface to provide the hot water supply for washing up, baths, etc., and, in addition, to heat one or two radiators for warming the house. In this case it is usual to have a separate flow and return to the radiators.

Where hard water is used, it is advisable not to pass the water for domestic supply through the boiler itself, otherwise after some time of working, deposits may be sufficiently great to impede the efficiency of heating. The most satisfactory arrangement is to heat the water indirectly in the manner illustrated in Fig. 4. M is the coke boiler on the left hand side of which are shown the connections for heating two radiators. On the right hand side is shown the hot water supply system. The hot water from the boiler simply circulates through a radiator K placed in the bottom of the hot water tank C. This is a closed system, and no fresh water is ever passed through the

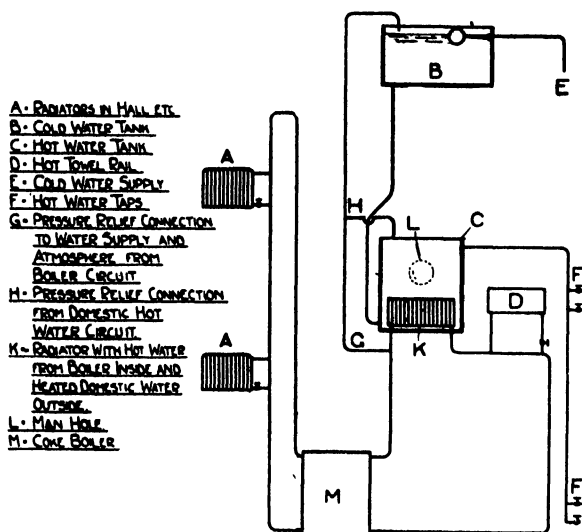


FIG. 4.—Domestic hot water system showing indirect heating of tank.

boiler itself. The heat of the water in the radiator K is imparted through the metal to the water in the tank C, which is provided with a cold water feed pipe and a flow pipe to the hot water taps F. There is the usual vent pipe H, which is also connected to the boiler circulating system by pipe G.

Such an arrangement as illustrated will supply all the hot water required for domestic use and supply two radiators and a towel rail by burning 2lbs. per hour of rin. coke at a cost (coke at 40/- per ton) of 1/- per day. In addition, water may be heated in pans or kettles on the top of the coke boiler and ordinary domestic refuse can be destroyed.

The best coke, properly graded, will give satisfaction in almost any domestic grate. An improved coke, such as I expect will be made at high temperatures in the not far distant future, will have all the desirable qualities of low temperature coke without its disadvantages.

I am not satisfied with the average coke made to-day when used in the best type of standard grate, but little improvement need be made as regards combustibility or ignitibility when it is intended to use it in either the Dr. Owen's type of fire (controlled draught) or in the enclosed central heating boiler. Much can be done in adapting burning equipment to coke in this way. One factor of importance, which is provided for in such equipment, including the "Esse" type of grate, is that as the coke burns it moves and the superficial ash is rubbed off each individual piece; combustion is accelerated and its radiant efficiency increased. This is a defect of the static well grate type of fire.

My ideal for house heating is a combination of hot water radiators and the radiant gas fire. When a coal fire is left last thing at night it serves a useful purpose in maintaining the temperature of the house overnight. Where gas

fires only are used, and they are turned off last thing, it is probable that, when relighted next day, the walls of the room in mid-winter will be so cold that the fire will have to be going for some time before the general wall chill has been eliminated. Semi-central heating, in halls and on landings, will maintain the temperature of walls in living rooms as well as all over the house, and the gas fire will provide that extra heat required in rooms occupied for longer periods.

The coal fire has some good points, but its disadvantages outweigh these. Coke is preferable for heating radiators and domestic water, on account of its freedom from smoke, and from the point of view of cost.

HEATING OFFICE BUILDINGS, ETC.

Large coke finds an admirable use in boilers of large size for supplying hot water to the radiators of large buildings. One such type is the Ideal Britannia boiler in which the coke is charged into a horizontal fire box entirely surrounded by water loops, which receive their heat partly by radiation from the glowing fuel bed, and partly from the hot gaseous products of combustion. The air enters through a controlled damper in the front of the ash pit, and the waste gases pass to the atmosphere through a flue at the back, fitted with a damper. The return enters at the bottom of the loops, and the flow is taken off at the top. These may be connected to the radiators of the ordinary type in different parts of the building by any of the usual systems of piping. I would, however, call your attention briefly to a system of heating which is finding considerable favour in new buildings. In place of the usual loop radiators which occupy space, are difficult to render æsthetic in appearance, and heat the air of the room mainly by creating convection currents of air, a series of small-diameter pipes embedded in the ceilings or the walls of the building are connected with a series of flow and return pipes. The small pipes heat the ceiling or wall in their immediate vicinity, forming a warm "panel" from which the heat is transmitted to the occupants by "radiation" and not by convection. Mr. A. H. Barker (Inst. of Heating & Ventilating Engineers, Oct. 5th 1926) has very fully described the underlying principles of this system. The main flow pipe is taken vertically to the top of the building, and thence one or more sections are taken round the top floor. At suitable intervals flow pipes are taken down to the bottom floor but are not connected directly to the return. At the level of each floor a connection is taken from these descending flow pipes to one end of a $\frac{1}{2}$ in. pipe which is embedded in the floor occupying a panel three feet wide, extending from the wall inwards. The other end of this pipe is connected to one of a series of return pipes which lead into the main return pipe. A variable speed circulating pump keeps the hot water in circulation throughout the system. The advantages of this arrangement may be summarised as :—

- (a) Considerable areas of ceiling and floor are warm, and the heat radiated from these provides an agreeable sensation of warmth without stuffiness.

- (b) There being a considerable mass of material at an elevated temperature, sudden changes in outside temperature have little or no influence inside. Conversely, this fact is a disadvantage if the circulation is not kept reasonably constant, as the response to quicker firing is rather slow.
- (c) No unsightly radiators are visible with a consequent saving in floor space.
- (d) It is claimed that only one third the radiating surface is required as compared with the "radiator" system and there is thus considerable saving in fuel.

COOKING BY COKE.

In concluding the review of the domestic uses of coke, I would refer to what may be termed the "Coke Kitchener" as exemplified by the "Ideal Cookan-heat," "Kooksjoie," etc. These are self-contained, requiring no back setting. They comprise a fire with water boiler, a cooking oven and a hot plate. The boiler may be of sufficient capacity to heat, in addition to the hot water for ordinary use, one or more radiators.

STEAM RAISING.

Whilst there is a ready sale for the various screened sizes of coke from $\frac{3}{8}$ in. upwards, there is a residuum of coke, known as unscreened breeze, which gas companies are willing to dispose of at lower prices. It is being realised that coke breeze, when burnt on a suitable grate, forms a very cheap fuel for steam raising and that it pays to install grates of a type which will successfully handle this fuel. Not only is the saving due to the low price of the coke breeze, but there is an increase in the thermal efficiency of the boiler due to the absence of volatile matter in the breeze which makes it possible to work the boiler with a reduced amount of excess air and eliminates all possibility of black smoke being emitted into the atmosphere. To burn coke breeze successfully requires the fuel bed in the first place not to be too thick, secondly, the air to be introduced under the fuel bed under pressure, and, thirdly, that there should be uniform distribution of the air.

For hand-fired furnaces, special grates such as the "Wilton" and "Turbine" grates are available. In both forms the air for combustion is injected by means of steam jets under specially arranged fire bars which are arranged so that each part of the fuel bed receives a uniform supply of air.

With chain grate stokers as such, only partial success has been achieved in burning coke breeze. Even with intimate mixing of the breeze and coal this was experienced, the chief difficulty being that the non-volatile breeze which generally contains appreciable amounts of moisture had the effect of cooling off the ignition arch and causing unburnt coal to be discharged over the end of the chain grate. Mr. E. W. L. Nichol, Engineer and Fuel Expert to the London

Coke Committee, introduced what is now known as the "Sandwich" system of firing boilers, and has give me the following notes on the application of his system : —

Probably few Londoners are aware that the electricity used for electric tramways and suburban electric railways is generated largely from gas coke, and in the provincial towns there are several instances where coke breeze is largely used. For example, at the Barton Power Station of the Manchester Corporation Electricity Department the boilers, each of 100,000lbs. per hour capacity, are equipped with the patent "Sandwich" system of burning coke or coke breeze in conjunction with low-grade coal slack.

The Barton power station was the most efficient power station in this country according to the Electricity Commissioners' Report, and when using 50 per cent. coke breeze, the overall efficiency obtained is 84.2 per cent. Similar installations of the Sandwich system are in use in the great electric power stations which supply the L.C.C. Tramways and the Southern Railway.

The Sandwich system is an extremely simple adaptation of the well-known chain-grate mechanical stoker. Instead of the usual single coal chute, it will be seen (Fig. 5.) that two chutes communicate with each mechanical stoker, and

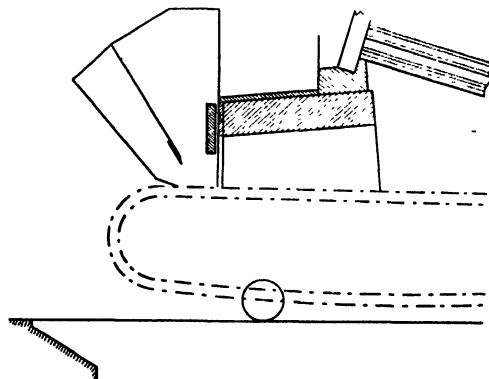


FIG. 5.—Sandwich System of burning coal and coke breeze.

with separate coal and coke bunkers overhead. The outer chute feeds the coke breeze, which is carried into the furnace in a 6 inch layer "sandwiched" between the chain grate and an upper layer of coal slack, fed from the inner chute, thus utilising instead of relatively high grade washed coal, two low-grade fuels in their natural untreated condition.

There are, of course, mechanical stokers which burn coke and coke breeze without the admixture of coal, but it is significant that these are being adapted to operate upon the Sandwich system, with a view to utilising also very low-grade coal which is otherwise considered unsuitable.

This outlet for coke breeze is also of great economic importance to the gas and coke-oven industries. Coke breeze, which is unavoidably produced to the

extent of about 10 to 12 per cent., has hitherto been used almost exclusively for steam raising in these industries, but waste heat boilers are now largely being adopted, especially in gasworks. The coke breeze thus released now finds a ready and convenient market, and forms an important source of additional revenue to the gas undertaking, the double economy thus effected tending to reduce the price of gas to the public, while, at the same time, adding another source of fuel supply to the electricity supply industry. During the war, and throughout the recent coal stoppages, coke and coke breeze, used on the Sandwich system, helped very materially to maintain public electric services, as great quantities of gas coke and breeze were used, some of the latter from dumps which had been in existence for over 50 years.

In concluding this section of the utilisation of gas coke, reference must be made to the use of coke on steam lorries and in coasting steamers. Two or three makers of steam wagons, such as the "Garrett," "Atkinson," "Yorkshire," "Sentinel" and "Leyland," provide special facilities for using coke only as fuel. With coke at 45/- per ton, a 6-ton "Sentinel" wagon fully loaded averages 15 miles per cwt. of coke, which is equivalent to less than 2d. per vehicle mile, or about one third of a penny per ton mile.

The gas coke most suitable for this class of work is coke broken to about 2in. size, which is available at about 1,600 gasworks in city, town and village throughout the country. In London and the Southern Districts there are many wayside depots organised by the London Coke Committee. The coke fired steam wagon is in general the cheapest form of road transport for heavy haulage. Combustion is of course entirely smokeless.

The use of gas coke in coasting steamers is a departure of recent years. Mr. E. V. Evans, Chief Chemist to the South Metropolitan Gas Company, has kindly given me the following notes on this Company's experience with gas coke as a boiler fuel on coasting steamers.

"The use of coke as a boiler fuel in the South Metropolitan Gas Company's steamships was first introduced in March 1925, the decision to make this alteration being largely influenced by the desire to assist in the smoke abatement campaign, particularly in relation to the River Thames.

"As was only to be expected, certain difficulties were encountered, when the change over from coal to coke was made, but these have now been overcome, and the results after two years' working are entirely satisfactory.

"Two ordinary single ended Scotch Multitubular boilers are used, each boiler having three Deighton's Corrugated Furnaces. The boilers develop about 1,000 Indicated Horse Power, and they are worked continuously at this power during the sea passage. Natural draught is used, it having been found that forced draught, i.e. hot air supplied by a fan under the firebars with a sealed ash pit, caused over-heating and collapse of the firebars. Certain types of

induced draught using steam jets as the means of induction have many advantages particularly with regard to cooling of firebars, but as applied to ships' boilers the extra amount of feed water necessary for this process is an important question. A typical installation on these lines is fitted to one of the Company's vessels, and the extra quantity of water used on a five day round voyage in comparison with a natural draught installation is 7 tons, there being a corresponding increase in fuel consumption.

"The increased wear and tear of firebars resulting from the use of coke fuel was one of the most difficult problems encountered. It was found that a bar having 1½ in. top and ¾ in. air space was the most efficient for combustion, but after the first three months, the quantity of firebars used was 100 per cent. more than for a similar period on coal. Eventually, it was found that a bar in one length which locks both at the back bridge and dead plate ends of the furnace, thus preventing distortion, was the most satisfactory. It may be noted that the bars should be box castings carefully finished, and not open sand, as is the general practice for coal, and the best results have been obtained by chilling the top of the bar.

"The type of coke used is No. 1 Broken coke, size 1—2 in. The material is easy to handle and generates steam with a minimum of exertion on the part of the stoker. It may be pointed out that stoking should be effected by filling in towards the back bridge and tapering towards the front dead plate—this procedure being exactly opposite to that employed with coal fuel.

"A comparison of the working results with coal and coke shows that as far as speed is concerned there is very little difference with the two fuels. With regard to fuel consumption, coke would appear to be slightly more economical than coal, the average figures for a round trip of five days being :—

Coal	...	...	...	...	58.18 tons.
Coke	...	...	...	...	55.99 tons.

"Since the adoption of coke as a fuel it has been possible to reduce the number of stokers actually employed on the fires from five to four. There has been no reduction in personnel, however, the extra man being employed in the engine room, the result being a considerable increase in the cleanliness and efficiency of the stokehold and engine room.

"It will be seen from the foregoing notes that for steamship purposes the advantages and disadvantages of coke fuel when compared with coal are briefly as follows :—

ADVANTAGES.

1. Entire absence of smoke.
2. Cleaner stokehold and engine room.
3. Reduction in stoking staff.
4. A slight reduction of fuel as compared voyage by voyage.

DISADVANTAGES.

1. Extra consumption of firebars.
2. Extra space required for bunkers, coal occupying 45 cu. ft. per ton, and coke 80 cu. ft."

INDUSTRIAL USES OF GAS COKE.

To review adequately this field would require more time than is available to-night. From the diagram already referred to (Fig. 1.) the uses of gas coke are multifarious, and are to be found in almost all branches of industry. I propose here to touch on one or two only.

PREPARATION OF FOODSTUFFS.

This industry, which touches one of the most intimate sides of our life, is represented by the use of gas coke in bakers' ovens. The heating of the baking decks is carried out by means of steam loop tubes in which water is evaporated under pressure placed in the roof and sole of the deck. The necessary heat is supplied by burning large gas coke screened over 2in. in furnaces, attached to the ovens. Since the baking operations are carried out at comparatively low temperature, steam is a convenient means of obtaining such temperatures without the oven being overheated in any part, and, under normal conditions, firing by gas coke is the cheapest means of obtaining the steam.

To turn to the preparation of another foodstuff, probably the enormous extent of the fish frying trade is not fully realised. Something like 5,000 tons of fish per week finds its way accompanied by the ubiquitous "chips" on to the tables of our Country. Large coke screened over 2in. is a suitable fuel for heating the "frying" pans of the fish shop. The advantage of coke as against coal apart from its price in this connection is its freedom from smoke, and its comparative cleanliness. It should however, be stated that the superior advantages of gas, even at a higher cost, is being realised, and in many cases all forms of solid fuel are being displaced.

Wherever small or large furnaces are required for heating purposes, large coke finds a very useful application. The smaller sizes of screened coke are also in many instances applicable. For example, the most suitable fuel for the well known smith's hearths is a washed breeze, either 1in. size for the larger type of hearths and about $\frac{1}{2}$ in. size for the smaller. Such smith's hearths are used in the manufacture of a variety of articles such as chains, garden requisites, etc.

PRODUCTION OF INDUSTRIAL GASES.

Gasworks themselves are very large users of coke. Of the 11,800,000 tons of gas coke made in this country, about 4,400,000 tons or over 37 per cent. is used on the Gasworks themselves in the manufacture of producer gas for heating the retorts and water gas for admixture with the coal gas.

Over three million tons of coke are used per year by the gasworks for the heating of the retorts, and the actual volume of producer gas obtained from this coke is greatly in excess of the coal gas made for distribution in the area of supply.

The type of producer almost exclusively used is the fixed grate producer with refractory walls. I am illustrating the step grate producer which is installed in Woodall-Duckham gas making plants (Fig. 6.). As will be seen, the grate is in

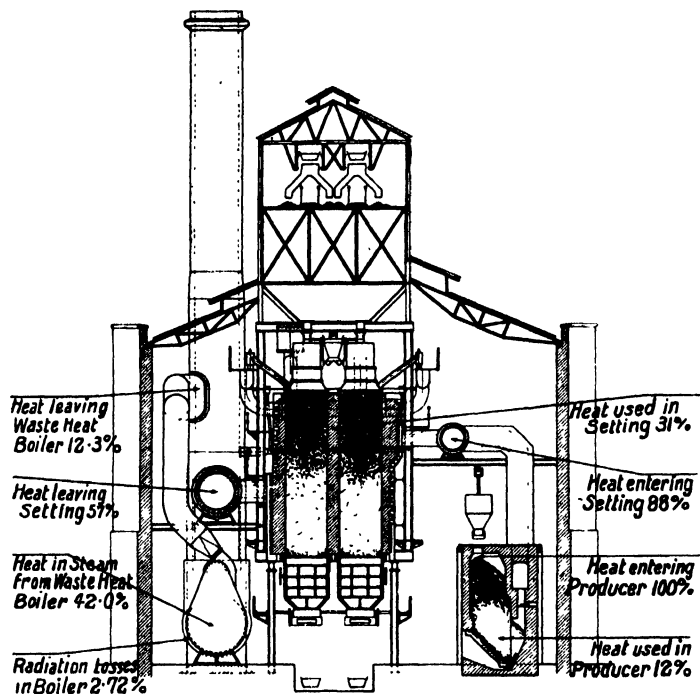


FIG. 6.—Step Grate producer applied to continuous vertical retort settings.

the form of a series of steps of iron plates, which are kept cool by a trickle of water. The coke which is generally screened large coke, is charged through the door in the top of the producer, which is always kept full of coke. The active incandescent fuel bed lies between the step grate and the curtain arch. The producer gas formed is drawn off under the curtain arch, and is distributed to the various combustion chambers round the retorts. The air for producer gas manufacture is introduced under the step grate by steam injectors. Such grates are dependent on manual labour for removing the ashes, but in this producer it has been reduced to small proportions. The same type of producer is largely used in general furnace work.

It has been found convenient in some instances in Gasworks and generally in other industries where producer gas is used, to install gas producers of the

Kerpeley type. The body of the machine is in the form of a water jacket which may either be cooled by a stream of water or by raising steam at low pressure. The grate is in the form of a perforated cone. This cone is attached to a horizontal pan which rotates slowly. The cone is of such a form as to have an eccentric movement, which as the grate rotates keeps the fuel bed in a gentle state of motion. The ashes as they form gradually work their way into the ash pan which is sealed with water, and are finally removed from the pan by means of a plough. The coke is charged through the hopper at the centre of the top, in such a manner as to keep the fuel bed as nearly level as possible. Air saturated with steam at about 65°C . is blown under the grate and through the perforated cone, the producer gas formed passing away through the outlet at the side. This type of producer works at maximum output with coke screened to $\frac{3}{4}$ in. to $1\frac{1}{4}$ in., all fines being removed. A producer of internal diameter will consume between 30 and 40 tons per day of this size of coke. When fed with coke from about $1\frac{1}{4}$ in. to dust, providing the amount below $\frac{1}{4}$ in. size is not greater than about 20 per cent., satisfactory working may be obtained, though the amount of coke gasified will not be greater than about 24 tons per day. The extra cost of a plant using unscreened coke may, however, be offset by a cheaper cost of fuel.

WATER GAS MANUFACTURE.

The modern trend of town's gas manufacture is to obtain a mixed coal and water gas direct from the gas retorts by introducing steam into the retort whilst coal gas making is proceeding. Where, however, the type of retort does not admit of this, the water gas is produced in a separate plant from large screened coke. In fact about 10 per cent. of the total gas coke made is used for this purpose. The type of machine usually used consists of a generator where a bed of coke is alternately brought to a high state of incandescence by an air blast, and then the heat thus stored is absorbed by passing steam through the hot coke. In contact with the coke, the steam is dissociated, the gaseous products of the reaction being hydrogen and carbon monoxide. This mixture of gases is cooled, purified and then mixed in definite proportions with the coal gas made direct from coal. In carburetted water gas machines, "blue" water gas passes immediately from the generator through another vessel where oil is sprayed on to heated refractory material. The vapours of the oil are carried with the water gas into yet a third vessel where in continued contact with heated refractory material the oil vapours are converted into permanent gases. Gas of calorific value from 300 to over 600 B.T.H.U. per cu. ft. may be obtained by varying the amount of oil used. It is most desirable that gas coke for use in water gas machines should be large coke free from small coke, and should not have a highly fusible ash, otherwise clinker troubles will be experienced. As a very useful figure, it may be taken that using a gallon of gas oil increases the calorific value about 100 B. Th. U's per

cubic foot. Generally speaking, there is about 52,000 cu. ft. of blue water gas made per ton of coke, and about 90 cu. ft. of oil gas per gallon of oil. The necessary steam may be raised from waste heat obtained during the periods when the coke is being "blown" with air, but steam may be obtained from an outside source when about 8lbs. of coke or breeze will be required to be consumed under boilers per 1000 cu. ft. of water gas made.

I think I have shown you enough to prove that coke is one of the chief economic factors in our national life. The multitude of its applications and uses, its advantages over the use of coal, its controllability, its cleanliness, and its availability, all commend it as a type of fuel that is worthy of still further development and improvement. It is fortunate that it is a product of a thoroughly progressive industry, employing technicians that are fully alive to all the possibilities, and I have no doubt that in the very near future, just as we have a number of Gas Light and Coke Companies, all gas undertakings will so recognise the national importance of the solid fuel they produce, that eventually we shall not have just a Gas Industry but a Gas and Coke Industry—or even a Fuel Industry. Then coke will have truly come into its own, and it will have the attention of research chemists, engineers and commercial men it deserves.

DISCUSSION.

The CHAIRMAN, in opening the discussion, said he thought they would agree they were indebted to Dr. Smith for a very lucid, comprehensive, and interesting survey of the subject. It was the function of the Chairman to do something in the way of opening the discussion, but he did not feel competent on that occasion to make a contribution of any value. He was deeply interested in the subject, and there were certain parts of it that he knew something about, but he could not bring what was most worth bringing into a discussion of that kind, namely, the record of one's own practical experience, as he had had very little to do with the domestic use of coke. Latterly his interest had been much increased, but, unfortunately, his opportunities had been very much diminished because he was living in a flat. But one thing which had been very much impressed upon him since he began living in a flat was how very important an open fire was and must remain as a destructor. That was an aspect apt to be very much under-estimated. He rejoiced in the possession of gas fires, but he did not know where he would be if he gave up his last open fire, which was the one and only destructor they had in the house. In ordinary household life, there were many things and many occasions for which one wanted the destructive agency of a fire. Another thing was the question of the bulk of coke as compared with coal. That was a fact which became well appreciated when one lived under the limitations of flat life in London. He had been awaiting the simple transformation of the domestic grate to enable coke to be properly burned and easily lighted, and burnt without the accompaniments from which coke had largely gained its bad character, one of which was dust, which flew about so easily. Coke had been a despised fuel and very unfairly despised, especially domestically. One of the elements in its bad reputation, which was quite undeserved, had been the suggestion that it gave off products of combustion of a particularly harmful kind, whereas coal was free from those objections as ordinarily burnt. It was surprising

to find the number of people who thought that coke was particularly sulphurous. He was glad that Dr. Smith retained a radiant element in domestic heating. The element of radiant heating, he thought, would be long regarded as indispensable in British houses. But we really must not use coal. One was delighted to see how the public conscience had become more sensitive on that subject in recent years. The first lecture he gave in the world of science in public was one at a Smoke Abatement exhibition, when he was a very young man. Since then there had been campaign after campaign with the object of persuading the public to clarify the air, and to help to rid the country of a pest which ought not to be inflicted upon it, and which might be very greatly and easily reduced. It seemed to him it was only in recent years that the public sense of the intolerableness of the smoke nuisance had become acute. He hoped all concerned with fuel technology would not be lacking in their efforts to bring to the public service heating materials and heating appliances which could be easily used to displace raw coal—a source of so much damage to the health of the community in the past.

DR. C. H. LANDER (Director, Fuel Research Board) said that only a few weeks ago, in that very room, a speaker complained that the paper he was delivering was almost impossible to discuss because it was all fact. He brought the same accusation against Dr. Smith. He had given them a series of very interesting facts concerning what could be done with coke and how various modifications might be made in appliances in order to get the best possible effect. The great question of the utilisation of coke was wrapped up with various national questions, of which the smoke nuisance was not the least important. One important aspect of the subject was the development of coke in such a way as to render its use more universal in existing appliances, as well as for people who were building new houses and could put in the very latest type of coke-using apparatus. He did not propose to refer in detail to the very striking work carried out by Leeds University in that connection, and also by Dr. Lessing in investigating the effects of small amounts of inorganic matter on the combustibility of coke. That work had led to most striking results which would have a bearing in the future in rendering it possible to use coke in appliances which had not been designed for its use. Another point which Dr. Smith made, and which he desired to amplify, was the importance of size and dryness in the suitability of coke. The man in the street was apt to look upon coke as coke, but, unfortunately, coke sometimes varied considerably in its quality. Sometimes a certain proportion of it was mineral matter which might or might not have a bad influence on its use, and some of it was water which in the past had reacted very greatly against the use of coke.

Atmospheric pollution really consisted of three things. One was the deposit of oily matter due to the visible smoke; another was the fouling of the atmosphere and the ultimate deposit of sulphur materials on stonework and buildings; and the third was dust. The problem of eliminating all three sources of pollution was not completely solved by even smokeless solid fuel, though very ardent protagonists would have them believe that that was the case. He would like to be able to peep thirty years into the future to see really what was going to happen, and whether the smoke nuisance was going to be mitigated by the production of a completely new type of fuel, or whether it was going to be prevented by the development of some of the striking work which was going on in the direction of making gas coke suitable for burning in furnaces which were not primarily designed for it.

MR. E. W. L. NICOL (London Coke Committee) had been impressed with one feature of Dr. Smith's excellent paper, namely, that without exception the domestic appliances on the screen, as well as the appliances in big power stations and coasting steamers, all called for graded coke, which was coke that had been sized to suit special requirements and sometimes washed. That impressed him with the importance of making provision at the gasworks for meeting that great potential demand for graded coke. He had been interested to hear quoted Mr. Evans' experience on his coasting steamers with regard to destroying fire bars by using coke instead of coal, as that was entirely contrary to his own experience and the experience of the public generally, who were steam users, and it would be unfortunate if that charge was levelled against the use of coke. His experience was that, with coal of the same anthracitic type as Welsh steam coal, the destruction of fire bars was much heavier than with; perhaps, any other fuel. Would Dr. Smith tell them why it was the impression seemed to be abroad that the sulphur content of coke was higher than that of coal? In gasworks the coal was carbonised at a very high temperature and the volatile sulphur was driven off and recovered as a valuable by-product. Consequently, it appeared to him that the volatile sulphur content of coke must necessarily be lower than that of coal. It was very important that coke should be supplied as dry as possible, but it had been found necessary to wash certain grades of the coke produced at gasworks for use in hot-water apparatus. That washed coke, although it contained more than the usual amount of water as a result of washing, was very much appreciated by the public. The public preferred to have washed coke notwithstanding its higher moisture content, and they were prepared to pay for the cost of washing.

DR. MARGARET FISHENDEN (Fuel Research Division, Department of Scientific and Industrial Research) remarked that there was little doubt that the most hopeful way of ameliorating the smoke nuisance was by an extended use of coke. In spite of the fact that the use of gas and electricity was extending very rapidly, the enormous amount of coal used for domestic purposes, amounting to forty million tons a year, did not show any signs of diminishing. It was a very large figure, and was more than the amount carbonised in the gasworks and metallurgical coke works put together. There clearly was an urgent need for some substitute for that solid fuel. She did not think that there were many heating purposes for which the **right sort** of coke could not be better and more cheaply used than coal. With the help of coke practically every class of house could be smokeless. In a large house open coke fires could be used in the rooms which were used a good many hours in the day, and gas fires, or possibly electric fires, could be installed in the intermittently used rooms; there would be a central heating installation with a coke fire and **probably** a separate coke-fired boiler for the domestic hot water supply. A moderate-sized house would have a smaller installation with one or two small radiators; while a small house would have to fall back on an open fire boiler, gas for auxiliary cooking, and coke for open grates. There were a good many kitcheners installed which were more suitable for burning coke than was thought, even though the coke when burnt might not act very well with regard to oven heat. But most types of modern open grates would burn coke quite satisfactorily. There was one point which had a bearing on the unpleasant smell sometimes associated with coke, namely, that in coke either the flames were very short or absent altogether, and the products of combustion after being mixed with cold air had to travel much further before they reached the throat of the chimney, and therefore there was a greater chance of their coming into the room if there was any cross draught, or any inclination to a down draught. Dr. Smith had pointed

out that a great deal of interest was being paid to that point, and that various types of specialised grates for burning coke were being put on the market. But in spite of that, it was fairly safe to say that very little was known about the conditions which obtained in open fires. In the light of future knowledge, grates ought to be designed to allow much closer control, and also to secure greater thermal efficiency.

There were one or two minor points in Dr. Smith's paper that she did not quite agree with, in connection with the proportions of radiation and convection in panel heating, and also from anthracite stoves. Unless an anthracite stove had a special arrangement for air circulation it would generally give as much radiation as convection, but it would be a more distributed radiation. The reason one did not associate the idea of radiation with an anthracite stove was partly because the rating was low, and partly because the radiation was distributed rather than because radiation was not emitted. Much the same thing was true in regard to extended surface heating. If the wall was the part of the room which was heated, the emission of energy was about half radiation and half convection. If the panel was in the ceiling the convection was checked and radiation was the chief source of heating. At the same time, it should be understood that in wall or ceiling heated buildings the ultimate effect of the energy going into the building was the same whatever its form was. It gradually warmed up the building. To claim that panel heating produced a very comfortable radiation without any other warming effect was not altogether an accurate statement of fact.

MAJOR P. H. RICHARDSON thought that the people responsible for coke getting a bad name were mainly the gas people. In the past they produced coke as a by-product of the manufacture of gas. One could take it or leave it. The Gas Companies were, however, now recognising that they were the potential heat suppliers of the nation, and with their habitual energy he thought they would take steps to see that their coke was suited to the purpose to which people wanted it put. Talking of open fires, the coal fires which they were so fond of gave practically little heat until the grate had acted as a gasworks, driving off the gas, tar, ammonia and sulphur, and all the other products, and turning the coal into coke; and the heat was mainly produced by radiation. Later on in the day, when the walls of the room had become heated by the air in contact with them, one got a considerable amount of convected heat. That was when the atmosphere became stuffy. In attempting to make any apparatus to consume coke for heating purposes, it was essential that it should work on the principle of radiation rather than convection. To obtain a radiant surface it was necessary to have practically perfect combustion. The ordinary coal grate which was made to burn solid fuel had more or less a horizontal fire bed, and one got a very much lower radiant heat given off in a useful direction until that fire had burnt into an incandescent state. The most important thing of all was to keep the radiant surfaces vertical. With a fire of a horizontal character the heat was mainly directed to the ceiling, but with a vertical fire the radiant heat was given off at right-angles and carried across the room at a useful level. It was an established fact that a room heated by radiant heat was comfortable at a temperature of 62 or 64 degrees, whereas, by convected heat only, one needed a temperature of 70 to 74 degrees to feel approximately the same degree of comfort. Another point to remember as to using stoves was that, in fixing a coke stove to burn solid fuel in a room, one usually blocked up all the openings of the chimney, and passed into the chimney only that amount of air which was necessary to promote combustion. With a properly designed grate to burn coke, one could pass all the air

into the chimney that the chimney could dispose of, a certain amount going through the fire to promote combustion, and the remainder going through the chimney above the fire to promote ventilation, and thereby good ventilation and removal of vitiated air was secured. If one overheated the air of a room one made it possible for that air to pick up more moisture, and one very soon got a stuffy atmosphere. If one did not leave room for all air to find an exit, the conditions were aggravated. Another point mentioned by Dr. Smith was the question of the destruction of household refuse. That was a very important point. There was no doubt that many millions of pounds could be saved if the local municipal authorities stated that they would not in future remove any combustible rubbish. In a "Glow-worm" coke fire there was as useful and desirable a form of destructor as one could possibly get. In destroying rubbish, one must make it possible for the stove or fire to carry away the products of combustion plus the odours that arose from that destructor. There were a few forms of apparatus on the market that would do that, but it must be understood that one must have a red-hot fire to start with, and that meant a radiant fire under control.

As to the qualities of the coke which was on the market, it was interesting to know that one town in the Midlands, which had paid far more attention to the production of graded coke and the washing of coke than any other town in the kingdom, was actually sending its coke to London and elsewhere and obtaining 15s. a ton more for it in competition, because people realised that that coke was worth far more money, since they were not buying a lot of waste material consisting of indestructible matter and water, as the coke was always dry-quenched. While many people imagined that moisture in fuel was most desirable, in fact it was not desirable, unless that moisture was near the temperature of the fire, namely, in the shape of steam. For intermittent purposes, the gas apparatus or some form of fire of that nature was useful for rooms which were only in partial use during the day; but everybody clung to the desire for an open fire. If the Gas Companies and other producers applied themselves to attempting to supplant that 40 million tons of coal used yearly in domestic grates, they could foster far more than anybody the removal of smoke in the country.

DR. J. G. OWENS (Hon. Sec., Advisory Committee on Atmospheric Pollution, Air Ministry) pointed out a somewhat curious thing with reference to the sulphur found in deposit from the air. When stations which had a very low deposit of total impurity were compared with those which had a high deposit, the sulphur percentage was always higher in the station with the lower deposit. The actual quantity was lower, but the percentage higher. There was another fact which had to be taken in association with that. He had recently been examining the figures for London and Glasgow. Since 1914 there had been a fairly steady reduction of the quantity of impurity in the air in both cities, in London particularly. Not only had the total impurity gone down, but the percentage of sulphur had gone down. It was the reverse of the other phenomenon. When comparing one station with another, apparently the percentage of sulphur did not go down at the same rate as the total impurity fell—whereas, when comparing one year with another in a city such as London, the sulphur went down more rapidly. Those were facts which he did not pretend to explain, but it was interesting to see that the efforts which had been made to reduce smoke had actually reduced sulphur also. It was important to remember that, because it was usually advanced against the smokeless fuel theory that one would not do away with sulphur even if one did away with the smoke. It had been proved that the reduction of smoke had done

away with sulphur to a great extent. The introduction of coke as a fuel had led to experimenting with it in ordinary domestic fires. For a good many years they had been trying to adapt fuel to the existing appliances and had almost ceased to consider the possibility of adapting the appliances to the fuel. Whichever method was right, there was no question about there being the two methods of dealing with the problem, either adapting the fuel to the existing apparatus or adapting the apparatus to the fuel, which was the more progressive method, as there were various other difficulties in the way of the further development of a fuel to suit the old appliances. One talked about heating houses, but really one put in fires for another purpose—to make the house comfortable to live in. Heating was one of the functions of a fire, drying was another, and providing suitable ventilation was another. If one sat in front of a black stove one certainly would not experience the same comfortable sensations as from sitting in front of a brightly radiant fire, and he supposed the failure to make life comfortable was a failure of the apparatus. The true meaning of the efficiency of fires was not clearly understood. One could not speak of the efficiency of an apparatus unless one knew what its function was. If one did not know what the function of a fire was one could not determine its efficiency. The simplest way to get the efficiency of a fire as a heating apparatus was to measure the loss from the top of the chimney. That was almost the only loss there was. One might get practically 100 per cent. efficiency. As a matter of fact, he had got close upon 100 per cent. efficiency from fires which he had tested. The result had been severely criticised as quite impossible, but it was perfectly true, being based upon the loss of heat at the exit of the chimney. He was glad to hear the Chairman remark that the public conscience was awakening more than ever to the necessity of purifying the air. It was an intolerable thing that they should pour into the air from their chimneys what one might call the sewage of their fires in the same way as one poured out some years ago other sewage into the rivers and trusted to Nature to take it away. Sometimes Nature took it away, but sometimes she failed, and she always failed to take it away completely unless she was given time enough.

MR. SVEND G. FIEDLER, A.M.I.H.V.E., who spoke as a foreigner from a country, Denmark, where there was a perfectly smokeless atmosphere, said that in about 1850 they had had their attention drawn to the use of coke as a splendid fuel. There was no doubt that an open grate could be made to burn coke very satisfactorily, and they had seen some examples of coke grates that evening which had interested him very much. The great disadvantage was that none of them could be kept burning during the night, but would have to be re-lit in the morning like open fires. The most desirable line to work along was to construct a grate that would burn as an open fire when desired, and could be closed down in a simple mechanical way, so that the fire might be retained as in a slow combustion stove during the night, keeping the room nice and warm and being drawn up again in the morning in a few minutes by the opening up of the draught. One speaker mentioned the necessity of adapting the fuel to the grate. In Denmark they found that coke was quite good as it was, and they had stoves which were suitable for burning it, but these stoves were not suitable for England. A good deal could be done in time to furnish new houses with suitable grates instead of keeping on putting in grates which were no good for the purposes they had at heart. With regard to the burning out of the fire bars, his experience was that cast iron or steel bars wore out much quicker in coke fires than in coal fires. He could not explain it, but that was his experience, and this was a point which future grate designers would find considerable difficulty in overcoming, for the user would not only be

interested in the new grate itself, and its fuel economy, but also in the cost of spare parts and repair. It was most desirable also to have coke a little moist. People in Denmark often put a jug of water on the coke when they thought it was too dry to put on the grate, but the consumer preferred to buy the coke dry, and himself add the water to it.

MR. JAMES CAWSON mentioned that a friend of his could produce a briquette which would utilise the refuse from the mines and would produce a calorific effect 20 per cent. greater than that of coal. Inasmuch as it could be used in an open grate, and made no dust, did not Dr. Smith consider that a briquette of that character might not be more effective than either coke or coal?

DR. SMITH said that he appreciated very much the way the discussion had gone, as there was really nothing left for him to reply to. The discussion had been additive, and as each speaker had asked questions they had been good enough either to answer them themselves, or had been followed by another speaker who had replied to them. On the question of sulphur in coke, there was less sulphur in coke than there was in the coal from which it was produced. The sulphur discharged into the atmosphere was probably in proportion to the sulphur content of either coal or coke, though it was quite conceivable there was a little more conversion and reduction where there was high radiant energy from coke than there would be in the case of coal, as some of the sulphur was volatile, and would not necessarily be converted to SO_2 . In spite of that, there was definitely less sulphur produced from coke than from coal. One could not let pass an occasion like the present without acknowledging Dr. Fishenden's wonderful work on the domestic grate. With regard to radiation, he was beginning to doubt the efficacy and the usefulness of high temperature radiation for heating purposes. He was a hundred per cent. believer in radiation, but there was something in the point which Dr. Fishenden hinted at, that low temperature radiation was probably better owing to its lack of intensity. He did not believe that it was comfortable to sit immediately in front of a first-class gas fire, as one immediately went off to sleep. What was wanted was radiant energy, but the reason for wanting radiant energy primarily was that this additive convected heat was never comfortable if it was higher than 65 or 70 degrees Fahrenheit. One knew that one's body had a much higher temperature than that. The only object of convected heat was to act as an insulator to prevent losses. The last thing to be desired in a room was that the heat of the air should be higher than the temperature of the walls. The air should be heated by the walls, not the walls heated by the air. If one could obtain radiant energy which heated the walls, then the walls should be at such a temperature as to give an equable temperature to the air. With regard to the point about briquettes, he did not think Mr. Cawson expected him to answer that question. One would say that the statement that briquettes were more effective was so doubtful that one would require to test the matter closely before giving any opinion on it. It was highly improbable that briquettes made from coal could be more efficient in their combustion than properly-made coke.

The meeting then terminated with a hearty vote of thanks to the Lecturer.

PROFESSOR CHAS. R. DARLING writes :—

The use of gas coke for domestic purposes has hitherto been restricted by the fact that coke will not burn freely in an ordinary open fireplace. This drawback has recently been overcome by the South Metropolitan Gas Company, who have devised a special grate, applicable to any existing open fireplace, in which coke

may be burnt readily. I have subjected one of these grates to a continuous test during the past few weeks, and have found it entirely satisfactory. The novelty lies in the use of narrow firebars, widely spaced, at the bottom of the grate, sloping at a considerable angle from the front to the back. In this manner a good air draught is provided, and, as the coke subsides on burning it slips down the incline and clears itself of ash. The back and cheeks are of firebrick. The installation of the grate in my case only necessitated the removal of the existing firebars and the substitution of the new arrangement, which is fitted with a row of gas burners for starting the fire. To initiate the combustion, the burners are lighted and kept on for about 15 minutes, after which the fire is self-sustaining. The coke used varies in size from $\frac{3}{4}$ to 2-inch lumps. For continuously warming a room, this firegrate is quite the best I have used, radiating better than a coal fire and producing the same ventilating effect without smoke or soot. The cost of fuel, so far as I can judge, is about equal to that of coal. Assuming—as appears to be the case—that gas coke may now be substituted for coal in open fireplaces, many important consequences follow. The production of semi-coke by low temperature carbonisation, on which so much capital has been expended, is rendered unnecessary; and those engaged in this process may now devote their attention to the yield of oil and other by-products, finally treating the residue so as to produce an ordinary gas coke. Again, the various organisations interested in smoke abatement, whose efforts have been largely ineffectual owing to the absence of a smokeless fuel for existing fireplaces, should be able to realise their aims now that a suitable grate for burning gas coke is available. A further problem which may arise is the adequacy of the supply of gas coke in the event of the general adoption of grates of this kind. Personally, I hope there will be no difficulty in this direction, as it is my intention permanently to instal coke fire grates in place of existing ones which burn coal.

NOTES ON BOOKS.

SILK: A MANUAL OF THE PROCESSES OF WINDING, WARPING, AND QUILLING this and other Yarns from the Skein to the Loom. By Samuel Kline. Second Edition. New York: John Wiley & Sons, Inc. London: Chapman and Hall, Limited. 10s. net.

Here is a practical book in quite the full sense of the term—how to do, and how to avoid sources of failure—a book which the author addresses mainly to the operatives in silk mills, with a hint that he who labours faithfully in detail may ultimately reach “mill ownership,” pp. IV-V.

The 21 illustrations range considerably in complexity; thus Fig. 5 merely shows the four standard knots of the warper or the winder, each knot being shown as loose or open, also as closed or drawn tight. On the other hand complex machines are well represented, as by Fig. 12, a Swiss beaming machine, or by Fig. 13, a warp in a power picking frame, with warp-rack alongside.

Mr. Kline, in a quiet and unobtrusive way, contrives to include much sound doctrine as to social and political economy, but he carefully avoids the many debateable issues which characterise the numerous partizan books on mixed politics and economics with which Great Britain is now overburdened. Thus the book is one which all classes may read with advantage, and a leisurely reading of the chapter on *Miscellaneous Matters*, pp. 82-98, may lead to trains of thought and conjecture which bear on Sir Josiah Stamp's recent speech (March 17), regarding the surprising industrial income of the United States at the present time.

GENERAL NOTE.

AN EXHIBITION OF PICTURES by J. W. Topham Vinall, A.R.C.A., N.S.A., Fellow of the Royal Society of Arts, entitled, "In and Around Westminster," will be held at "The Abbey Gallery," 2, Victoria Street, Westminster, S.W.1, from 11th May to 4th June next; 10 a.m.—5.30 p.m. Saturday, 10 a.m.—1 p.m. Admission free. Fellows of the Society and their friends are cordially invited.

MEETINGS OF OTHER SOCIETIES
DURING THE ENSUING WEEK.

MONDAY, MAY 9. Geographical Society, Lowther Lodge, Kensington Gore, S.W. 5 p.m. Major Kenneth Mason, "The Stereographic Survey of the Shaksgam." Royal Institution, 21, Albemarle Street, W. 5 p.m. General Meeting.

Surveyors' Institution, 12, Great George Street, S.W. 8 p.m. Mr. A. M. Trustram Eve, "The Practical Application of the Rating and Valuation Act, 1925." University of London, at the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Dr. Otakar Voadlo, "Czech and English: Some Linguistic Parallels." At King's College, Strand, W.C. 5.30 p.m. Prof. F. C. Montague, "Some Modern English Historians." (Lecture II.). "Gardiner." At University College, Gower Street, W.C. 5 p.m. Prof. Dr. G. Dawes Hicks, "Ruskin's Theory of Art." (Lecture II.).

TUESDAY, MAY 10. Anthropological Institute, 52, Upper Bedford Place, W.C. 8.30 p.m. Mr. E. G. Bowen "Anthropological Types and Tuberculosis." Civil Engineers, Great George Street, S.W. 6 p.m. Annual General Meeting. Colonial Institute, at the Hotel Victoria, Northumberland Avenue, W.C. 8.30 p.m. General Viscount Byng of Vimy, "The Canadian at Home." Marine Engineers, Institute of, 85-88 The Minories, E. 6.30 p.m. Mr. Horace J. Young, "Some Metals and Methods of use in Marine Engineering." Petroleum Technologists, Institution of, at the ROYAL SOCIETY OF ARTS, Adelphi, W.C. 5 p.m. Petroleum Technologists, Institution of, at the ROYAL SOCIETY OF ARTS, Adelphi, W.C. 5.30 p.m. Messrs. J. Kewley and J. S. Jackson, "The Burning of Mineral Oils in Wick-fed Lamps."

Quekett Microscopical Club, 11, Chandos Street, W. 7.30 p.m. Mr. D. Ward Cutler, "The Effect of External Conditions on the Soil Micro-Organisms." Royal Asiatic Society, 74, Grosvenor Street, W.1. 4.45 p.m. Lieut-Col. C. E. Luard, "Ahalya Bai Holkar and her contemporaries."

University of London, at Birkbeck College, Bream's Buildings, E.C. 5.30 p.m. Prof. Maj.-Gen. Sir Frederick Maurice, "Joffre, Gallieni and the Marne—A Reply to Mr. Churchill."

At the Royal School of Mines, South Kensington, S.W. 5.30 p.m. Dr. F. F. Blackman, "Problems of the Respiration of Plants." (Lecture I.). At King's College, Strand, W.C. 5 p.m. Prof. Dr. R. J. S. McDowall, "Autonomic Nervous System." (Lecture II.).

5.30 p.m. Prof. A. Michotte, "Problems of Mental Work." (Lecture I.).

5.30 p.m. Dr. Ernest Baker, "Christianity and Nationality."

At University College, Gower Street, W.C. 5.30 p.m. Mr. W. H. McLean, "National, Regional and Town Development Planning." (Lecture I.).

Zoological Society, Regents' Park, N.W. 5.30 p.m. Scientific Business Meeting.

WEDNESDAY, MAY 11. Archaeological Institute, 19, Bloomsbury Square, W.C. 5 p.m. Dr. R. E. Mortimer Wheeler, "London and the Vikings: New Materials."

Electrical Association for Women, at the Hotel Cecil, Strand, W.C. 11.30 a.m. Annual General Meeting. Geological Society, Burlington House, W. 5.30 p.m. Metals, Institute of, at the Institution of Mechanical Engineers, Storey's Gate, S.W. 8 p.m. Sir Henry A. Miers, F.R.S., "The Growth of Crystals in Super-saturated Liquids."

Model Abattoir Society, at 32, Chesham Place, S.W. 5 p.m. Annual Meeting. Addresses by Sir Arthur Newsholme and Prof. H. Kenwood.

University of London, at King's College, Strand, W.C. 5.30 p.m. The Rev. Maurice Rulton and Miss Evelyn Underhill, "The New Prayer Book." (Lecture I.). At the London School of Economics, Houghton Street, Aldwych, W.C. 5 p.m. Dr. Hubert Hall "Housekeeping in Six Centuries (1200-1800)." (Lecture III.).

At the School of Oriental Studies, Finsbury Circus, E.C.2, 12 noon. Mr. T. A. H. Way, "Indian Administrative Law." (Lecture III.). 5 p.m. Count Leon Ostrosorg, "The Reform of Turkish Law." (Lecture I.).

THURSDAY, MAY 12. Aeronautical Engineers, Institution of, at the ROYAL SOCIETY OF ARTS, Adelphi, W.C. 8.15 p.m.

Antiquaries Society, Burlington House, W. 8.30 p.m. Historical Society, 22, Russell Square, W.C. 5 p.m. Mme. Lubimenko, D-és-Lres, "Anglo-Russian Relations, 1642-1689."

Linnean Society, Burlington House, W. 5 p.m. Oil and Colour Chemists' Association, at 8, St. Martin's Place, W.C. 8 p.m. Annual General Meeting. Mr. Ade Warle, "Some Physical Factors influencing Properties of Paint Pigments."

University of London, at King's College, Strand, W.C. 5.30 p.m. Prof. A. Michotte, "Problems of Mental Work." (Lecture II.).

5.30 p.m. M. Jean Richard Block, "Où va le Théâtre Français Actuel?" (in French).

5.30 p.m. Dr. Antonio R. Pastor, "Contemporary Developments in Spanish Literature—A Survey of General Tendencies with Particular Reference to the Effects of the War."

At University College, Gower Street, W.C. 5.30 p.m. Prof. Dr. A. F. Pollard, "The Balance of Power in History."

FRIDAY, MAY 13. Astronomical Society, Burlington House, W. 5 p.m.

Junior Institution of Engineers, 39, Victoria Street, S.W. 7.30 p.m. Paper by Mr. W. A. Sallis.

Physical Society, at the Imperial College of Science, South Kensington, S.W. 5 p.m.

Royal Institution, 21, Albemarle Street, W. 9 p.m. Prof. Sir Humphry Rolleston, "Concerning Old Age."

University of London, at King's College, Strand, W.C. 5.30 p.m. Prof. A. Michotte, "Problems of Mental Work." (Lecture III.).

5.30 p.m. Mr. F. H. Marshall, "Delphi, Olympia and Delos."

At University College, Gower Street, W.C. 5.30 p.m. Prof. Dr. John Burnet, "Platonic Problems." (Lecture I.).

SATURDAY, MAY 14. Arts, League of, at the Victoria and Albert Museum, South Kensington, S.W. 3 p.m. Mr. Otto Sallmann, "Shakespeare."

Transport, Institute of, at the Midland Hotel, Manchester, 6.30 p.m. Annual General Meeting.

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All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2.)

NOTICES.

NEXT WEEK.

WEDNESDAY, MAY 18th, at 8 p.m. (Ordinary Meeting.) ROBERT R. HYDE, Director, Industrial Welfare Society, "Industrial Welfare in Great Britain and the United States." SIR ROBERT A. HADFIELD, Bt., D.Sc., F.R.S., a Vice-President of the Council, will preside.

NINETEENTH ORDINARY MEETING.

WEDNESDAY, MAY 4th, 1927. BRIGADIER-GENERAL SIR BRODIE H. HENDERSON, K.C.M.G., C.B., M.Inst.C.E., in the Chair.

The following candidates were proposed for election as Fellows of the Society :—

Bishop, Walter Frederick, Enfield, Middlesex.
Hedgcock, Archibald John, Purley, Surrey.
Keay, George Edmund, Birmingham.
Potter, William Joseph, London.
Pratt, Major James A., Delaware Co., Penna., U.S.A.
Rosling, Percy, Shortlands, Kent.
Salmon, Arthur Edward, Bourne End, Bucks.
Sherman, William G. Matthews, Brimsdown, Middlesex.
Weidlein, Edward Ray, M.A., Sc.D., Pittsburgh, Pa., U.S.A.

The following candidates were duly elected Fellows of the Society :—

Gates, E. Everard, London.
MacDougall, Alexander, Thornton Heath, Surrey.
Ramsden, Thomas, Wigan.

The first of a course of two lectures given under the Dr. Mann Trust was delivered by Professor William E. DALBY, M.A., F.R.S., M.Inst.C.E., M.I.Mech.E., Dean of the City and Guilds (Engineering) College, Imperial College of Science and Technology.

The lecture will be published in the *Journal* dated July 1st.

INDIAN SECTION.

FRIDAY, MAY 6TH, 1927. SIR EDWARD A. GAIT, K.C.S.I., C.I.E., Member of the Council of India and Chairman of the Indian Section, in the Chair.

A paper on Assam, which was illustrated by lantern slides, was read by Mr. B. C. ALLEN, C.S.I., late Commissioner, Assam Valley Division.

The paper and discussion will be published in the *Journal* dated July 15th.

CANTOR LECTURE.

MONDAY, MAY 9th, 1927. MR. JOHN W. T. WALSH, M.A., M.Sc., F.Inst.P., A.M.I.E.E., Senior Assistant, National Physical Laboratory, and General Secretary, International Commission on Illumination, delivered the third of his course of three lectures, illustrated by experimental demonstrations, on "The Measurement of Light." On the motion of the Chairman MR. L. GASTER, a vote of thanks was accorded to the lecturer for his interesting course.

The lectures will be published in the *Journal* during the summer recess.

BINDING COVERS FOR JOURNALS.

For the convenience of Fellows and others wishing to bind their annual volumes of the *Journal*, cloth covers can be supplied, post free, for 2s. each, on application to the Secretary.

PROCEEDINGS OF THE SOCIETY.

INDIAN SECTION.

FRIDAY, MARCH 11TH, 1927.

SIR THOMAS H. HOLLAND, K.C.S.I., K.C.I.E., D.Sc., F.R.S.,
Chairman of the Council, in the Chair.

THE CHAIRMAN, in introducing the author, said Mr. Mather had been interested in the subject of iron and steel almost from the time he entered the cradle; he was Sheffield-born, Sheffield-bred and a Sheffield graduate. So far as India was concerned, the author's experience was of a special type. He went out to India in 1919 as Chief Metallurgical Inspector on behalf of the Government, and nine-tenths of his work consisted in dealing with steel supplies from the Tata Iron and Steel Works, the remainder of his work being in connection with other metallurgical products. The author had thus seen the Indian iron and steel industry from a detached point of view. Recently he had been back to India again to advise the Government with regard to the very vexed question of a tariff, so that he had seen the industry again from another point of view. The paper would, therefore, be of more than usual value, because the author had not only the technical knowledge, but was free from any form of prejudice from the commercial point of view.

The following paper was then read:—

THE IRON AND STEEL INDUSTRY IN INDIA.

By RICHARD MATHER, B.Met.,

Late Metallurgical Inspector, Government of India.

It is now about nine years since the Indian iron and steel industry was described in a paper read before the Royal Society of Arts. The developments which have taken place since Mr. Tuckwell presented his paper in 1919 are sufficiently great to justify the hope that a description of the present position may be of interest.

The indigenous methods of iron-making in India have not entirely died out, but their use has so diminished that they no longer have any industrial importance. These methods have been frequently described elsewhere and they will therefore not be discussed in the present paper. Similarly, no attempt will be made to re-capitulate the early history of the manufacture of iron and steel in India by modern methods. Accounts are already available of Heath's attempts nearly a century ago to establish the manufacture of pig iron in Madras; of the somewhat later enterprises in Central and Northern India; of the early stages of the undertaking which has now become the Bengal Iron Company; and of the origin of the Tata Iron and Steel Company. The main purpose of the present paper is to describe the present position of the industry and its immediate prospects.

It should be made clear at the outset that there is no manufacture of wrought iron in India. This industry, which has dwindled so rapidly in Europe and America, never obtained a footing in India, nor is there any prospect that it will do so. The iron made in India is exclusively pig iron either for conversion into iron castings or into steel, or for export.

RAW MATERIALS.

The Indian iron and steel industry is based entirely on indigenous materials, of which the chief are iron ore, coking coal, gas coal, limestone, dolomite, manganese ore, and (in Mysore) charcoal. In addition, practically all the refractory materials used for furnace linings are produced from Indian minerals. These fundamental and accessory minerals can be described only very briefly in this paper. A fairly full account has recently been given by Dr. C. S. Fox, of the Geological Survey of India.*

Iron Ore. Deposits of iron ore of high quality occur in several parts of India, notably in Bihar and Orissa, Mysore, the Central Provinces, Madras, the United Provinces and Burma. Many of the deposits are situated at such distances from the deposits of coking coal that economic working is clearly impossible in present circumstances, and the surveys have accordingly not

*Trans. Min. and Geol. Inst. of India, 1925 (vol. XX), p. 87.

been sufficiently complete to justify more than the statement that India contains large reserves of high grade ore in deposits which have so far not been worked.

The Mysore deposit consists of hematite having an average content of probably 60 per cent. of iron. The deposit occurs in the Bababudan Hills and is believed to contain about 25 to 60 million tons of ore. The present rate of extraction is about 40,000 tons annually (average) and there is no reason to anticipate any very large increase in this rate during the next few years.

The only other deposits which are being worked for iron manufacture are those of the "Iron Belt" in the Province of Bihar and Orissa. The parts of this belt which are at present being worked lie in an area about 20 to 50 miles south of the main line of the Bengal Nagpur Railway from Calcutta to Nagpur and about 120 to 200 miles west of Calcutta. The deposits are partly in the Singhbhum District and partly in the Feudatory States of Mayurbhanj, Bonai and Keonjhar. The ore in the two last-named States has not been worked up to the present, but the rate of extraction in Mayurbhanj has so far been much greater than that in Singhbhum. This position will, however, probably be reversed during the next year or two. In 1926, over 1½ million tons of ore were extracted from these deposits, which thus form the basis of the large-scale iron industry in India. The ore is a fairly pure hematite, containing between about 58 and 68 per cent. iron. Although some portions of the ore contain very little phosphorus (under 0.03 per cent.) the bulk of it appears to contain about 0.1 per cent. The ore can be won by open working and in very few places is there any appreciable amount of cover to be removed. Two branch lines of broad gauge railway and one of narrow gauge have been constructed to carry the ore to the main line of the Bengal Nagpur Railway.

The quantity of rich ore in these deposits has not yet been ascertained with any great accuracy. The provisional estimate is that the quantity is approximately 3,000 million tons of ore containing about 60 per cent. or more of iron. A detailed survey of the Noamundi lease is now being made by Mr. F. G. Percival, of the Tata Iron and Steel Company, and his results may be expected to give a better indication than has yet been available of the accuracy of this figure. There is, however, little reason to doubt that this part of India contains a larger deposit of high grade iron ore than any other known deposit which is within 200 miles of deposits of coking coal.

Coal. The main fuel requirement of the iron and steel industry is coking coal. This is at present obtained almost entirely from the Jharia coal field in Bihar and Orissa. The knowledge at present available suggests that the amount of good coking coal in India is much less than that which would be required to smelt the "Iron Belt" deposits of iron ore by existing methods. But a detailed examination of the coal fields, which has recently been under-

taken by the Geological Survey of India, may be expected to give more precise information on this point. It seems, however, safe to say that there is a sufficient reserve of good coking coal within a reasonable distance of the ore to provide all the steel required by India for at least one hundred years, unless there is a rapid increase in demand—a contingency which can by no means be overlooked. The coking coal referred to above would not be considered good in Europe since, with small exceptions, it contains so much ash as to yield a coke containing about 20 per cent. of ash. This drawback is, however, not very serious in India where the ores are so rich. The mechanical properties of the coke are good and the sulphur content is reasonably low. A further special feature of the coke is that it contains a high proportion of phosphorus and thus furnishes the greater part of the phosphorus content (0.3 to 0.4 per cent.) of ordinary Indian pig iron, which necessitates the use of a basic process of steel-making. In the manufacture of steel on a large scale with modern equipment no important quantity of coal should be required other than that which is required for the coke. In so far as gas coal is needed it can be obtained from the Raniganj field in Bengal and steam coal is available in both the Bengal and Bihar deposits.

Fluxes. Limestone is required for use as a flux in blast furnaces and in basic steel-making; dolomite can also be used as a blast-furnace flux and is required as a lining for basic steel furnaces. While the purest deposits of these minerals in India are at relatively large distances from the iron and steel works, it has been found possible with proper care in extraction to obtain supplies of good quality from various deposits in Chota Nagpur and the Central Provinces.

Fluor spar is also used on a small scale as a flux in basic steel-making processes. No deposits which are economically workable have yet been found in India and the requirements are met by importation.

Manganese Ore. The importance of India in the world's supply of manganese ore is well known and the small quantities needed by the iron and steel industry of the country can probably be met for very many years from the known reserves. The conversion of the ore into ferro-manganese for export has, however, so far been very limited, as the high content of iron and phosphorus in the ash of ordinary Indian coke has made it impossible to supply ferro-manganese of the richness and purity ordinarily required by European and American steel works. It is possible, however, that in the near future an attempt may be made to render available for ferro-manganese manufacture part of the small amount of relatively pure coking coal which is known to exist. If this is successful, a substantial export of ferro-manganese may be developed.

Charcoal. As there are large forests in Mysore, but no coal, the blast furnace at the Mysore Iron Works uses charcoal instead of coke. The wood is

carbonised in retorts connected with a by-products plant, which recovers or produces wood-tar, methyl alcohol and calcium acetate.

Refractory Materials. Firebrick and Silica brick of good quality can be made from deposits of fireclay and quartzite occurring in or near the coalfields. Quartzite for the lining of Bessemer converters (acid) is obtained near the Tata works at Jamshedpur.

Magnesite, which is required mainly for the lining of basic steel-making furnaces, occurs in Madras, Mysore and Baluchistan, but owing to the lack of a suitable brick-making plant and to the long railway haulage from the deposits to the steelworks, the magnesite bricks used in India have mainly been imported. It is, however, probable that during the next two or three years arrangements will be made to manufacture in India the magnesite bricks required.

MANUFACTURE OF PIG IRON.

Pig iron is made in India by the Bengal Iron Company, the Tata Iron and Steel Company, the Indian Iron and Steel Company and the Mysore Government. The production (to the nearest thousand tons) during the last three calendar years is shown in the following table :—

	1924.	1925.	1926.
Bengal Iron Company ...	148,000	53,000*	20,000* tons.
Tata Iron and Steel Company	540,000	563,000	609,000 ..
Indian Iron and Steel Company	168,000	247,000	253,000 ..
Mysore Iron Works ...	16,000	17,000	20,000 ..
Total	872,000	880,000	902,000 ..

* Partial operation only.

The total production in India in 1913-14 was only 218,000 tons. It will thus be seen that by 1924 the production was four times the pre-war production and that there has since been a further increase.

Bengal Iron Company. The works of this Company are situated on the Raniganj coalfield at Kulti, 142 miles north west of Calcutta. The ore is now drawn from the Singhbhum deposits about 160 miles south-west of the works. The Company makes its coke at the works and possesses five blast furnaces, of which only the newest is mechanically charged. The plant has a rated capacity of 200,000 tons of pig iron annually, but owing to market conditions operations have been on a reduced scale during the last two years. The Company makes only foundry iron, of which the following analysis may be taken as representative.

BENGAL M.				
Total Carbon	...	3.4	per cent.	
Silicon		1.5 to 3.0	..	
Manganese		1.0 „ 1.5	..	
Sulphur		0.02 „ 0.05	..	
Phosphorus		0.3 „ 0.4	..	

The above composition is typical of that of Indian pig iron made from Singhbhum ore and ordinary Indian coke. The Bengal Company also makes iron (Bengal P) containing between 0.6 and 1.0 per cent. phosphorus for use in the manufacture of light castings. This is obtained by specially charging into the furnace a suitable proportion of phosphate rock (usually containing iron also) which is obtained from deposits near Tatanagar in Singhbhum. In recent years the greater part of the Company's output of pig iron has been used in its own iron-foundries (the largest in India) and in other Indian foundries. In 1926 the Company produced about 71,000 tons of iron castings.

Tata Iron and Steel Company. This Company, which produces two-thirds of the pig iron made in India and almost all the steel, has its works at Jamshedpur (formerly Sakchi), about two miles from Tatanagar Station, which is about 155 miles west of Calcutta on the main line of the Bengal Nagpur railway. The coalfields are north of the works, the distances by rail averaging about 115 miles. Coke is made in a large coke-oven plant at Jamshedpur. Ore is at present being brought from three deposits in Mayurbhanj, south of Jamshedpur, the average haulage being under 50 miles, and from Noamundi in Singhbhum, which is nearly 80 miles south-west of Jamshedpur. Dolomite and limestone are at present brought chiefly from workings in Gangpur State, about 110 miles west-south-west of Jamshedpur.

The early development of this Company's works has been described in the interesting paper presented to the Society in 1919 by Mr. Tuckwell, to which reference has already been made. The original plant had only two blast furnaces; a third was brought into operation in 1919; and in December, 1922, and January, 1924, respectively, the fourth and fifth furnaces were put in blast. The capacity of the two newest furnaces is such that the outputs of 1925 and 1926 were obtained from four furnaces only. Two of the old furnaces have recently been re-lined in accordance with modern ideas, and when the remaining furnace is similarly treated the producing capacity of the blast furnace plant, if adequate blowing power is available, will hardly be less than 900,000 tons of pig iron annually. Much the greatest part of the output is basic pig iron for the Company's own use. The Company also uses foundry iron for ingot moulds and miscellaneous requirements of the works, sells foundry iron to other users in India and exports both basic and foundry iron.

The Indian Iron and Steel Company commenced the manufacture of pig iron towards the end of 1922 in a newly-erected plant in the coal field near

Asansol and about 10 miles from the works of the Bengal Iron Company. The Company has not yet developed its coal area, but makes coke at its own works from purchased coal. The ore is brought from Gua in Singhbhum and limestone from Gangpur State. The plant consists of two blast furnaces of modern type, of which one makes about 400 tons of iron per day and the other, which has recently been re-lined, is now making about 600 tons daily. The Company does not produce iron castings (other than the small quantity required for its own purposes) nor does it make steel. Thus practically the whole of the iron is made for sale, the bulk of it being exported from India. Much of the iron exported is of basic quality for steel making.

Mysore Iron Works. These works were erected shortly after the War and are operated by the Mysore Government. They are situated at Bhadravarti. The plant consists of one blast furnace of rated capacity 60 tons per day and the wood distillation plant (which has already been referred to) for the production of charcoal. This furnace is probably the only charcoal blast furnace in the world which has been erected in recent years. The phosphorus in the pig iron varies between 0.11 and 0.13 per cent. and the sulphur is usually below 0.02 per cent. The iron is used for miscellaneous foundry purposes and for pipes, for which a new foundry was erected last year. During the calendar year 1926 over 8,000 tons of the pig iron were exported.

MANUFACTURE OF STEEL.

Although there is only one works in India, namely that at Jamshedpur, in which steel is made on a scale which is of industrial importance, there are several small steel works. These may conveniently be referred to first.

Government Metal and Steel Factory, Ishapore. In the ordnance factory at Cossipore maintained by the Army Department of the Government of India, the manufacture of steel in a small acid furnace was commenced in 1892. The plant was transferred in 1906 to Ishapore and has been developed gradually until there are now three 20-ton acid open-hearth furnaces. The production is chiefly ingots, which are rolled in an 18-inch mill or a 10-inch mill to the sections required. The plant is worked to meet Ordnance Factory requirements. The rated capacity is 12,000 tons of ingots, or about 10,000 tons of bars, yearly. In 1926, 6,020 tons of ingots and about 30 tons of castings were produced.

East Indian Railway. In 1898 this railway erected at its Jamalpur works a small open-hearth furnace (acid), mainly with the intention of converting its regular supply of scrap (for which no market was available) into usable steel. The plant now has two 15 ton furnaces, both of which are basic-lined, and has three mills, 18, 14 and 10-inch respectively, for rolling the ingots into the billets, bars or small sections required. The output in the three calendar years 1924, 1925 and 1926 has varied very little from the average

of about 7,000 tons of ingots (6,000 tons rolled steel) and 300 tons of castings.

Bombay, Baroda and Central India Railway. In 1906 this railway installed a small side-blown converter of two tons capacity in its Ajmer works for the production of the steel castings required by the repair and construction departments, there being at that time no source of supply of steel castings in India. The railway builds its own metre-gauge locomotives and most of its castings are used in connexion with this work and in locomotive and wagon repairs. Production of castings:—Calendar year 1924, 740 tons; 1925, 840 tons; 1926, 790 tons.

Hukumchand Electric Steel Works. The erection of these works (of which the proprietors are Sir Sarupchand Hukumchand and Co.) was commenced in 1920 and the manufacture of steel began in 1922. The plant is situated at Ballygunge, a suburb of Calcutta, and consists of two 2-ton electric furnaces and a foundry for the production of steel castings. Electric power is obtained from the Calcutta Electric Power Corporation at rates which would not exceed $\frac{1}{2}$ anna per unit if the works were in full and continuous operation. Up to the present the output of steel has never been more than a small proportion of the capacity, the production of castings having been about 510 tons in 1924, 760 tons in 1925 and 390 tons in 1926. During the last year, however, the works produced also about 150 tons of steel for springs, as it has acquired small rolling mills (20, 16 and 10 inch respectively), part of which it proposes to erect for the purpose of producing spring bar and other kinds of high carbon bar. The firm applied to the Indian Tariff Board in 1926 for protection for the manufacture of steel castings and spring steel. The result of the application has not yet been announced.

Kumardhubi Engineering Company. This firm is mainly occupied in the manufacture of structural steel work of various kinds. In connexion with the development of its business in aerial ropeways it erected in the autumn of 1926 a 5-ton acid open-hearth furnace for the production of steel castings in its works on the Jharia coal field. The plant has not been at work for a sufficient time to enable the results to be available. It is understood that the firm has also taken over the operation of an adjacent small mill which re-rolls scrap steel and wrought iron bars to marketable sections.

Tata Iron and Steel Company. The development of the steel making plant and rolling mills of this Company since the date of Mr. Tuckwell's paper has been fully as important as that of the blast furnaces. The original open-hearth plant of four furnaces has been enlarged by the addition of three 70-ton furnaces; and an entirely new steel-making plant, working on a duplex process, has been erected. In this plant the molten pig iron is partially refined in an acid lined converter and the refining is finished in a 200-ton tilting open-hearth furnace, basic lined. This plant, with two converters and two tilting furnaces, has in a recent month made over 32,700 tons of ingots, while the open-hearth plant made 21,500 tons of ingots in the same month. The two

steel-making processes are largely complementary one to the other, for the duplex process cannot consume the scrap resulting from the rolling of the ingots made by it, while the open-hearth process works more economically if a larger supply of scrap is available than results from the rolling of its own ingots. The Tata works are practically self-contained, in that no melting scrap is sold and almost none is bought from outside.

The rolling-mills originally erected by the Company are all steam-driven and are of relatively small capacity. They have now been supplemented and almost superseded by the large equipment of new mills, all electrically driven, which came into operation in 1923 and 1924. Of nearly 35,000 tons of rolled steel produced in a recent month less than 5,000 tons were rolled on the old mills. The Company can now produce rails, fishplates, steel sleepers, structural sections (beams, channels, angles and tees), bars, plates, tinbars, black sheets and galvanised sheets (corrugated or plain). The following table shows the output of rolled steel in the last two calendar years.

				1925.	1926.
Rails—					
(a) Medium and heavy	...	...	...	115,300	145,000 tons
(b) Light	...	...	...	3,300	4,300 "
Fishplates	...	...	...	4,700	6,400 "
Steel sleepers	...	...	...	1,600	600 "
Structural Sections—					
(a) Medium and heavy	...	...	...	25,300	28,600 "
(b) Light	...	...	...	19,800	15,300 "
Bars	...	...	...	52,300	60,600 "
Plates	...	...	...	20,000	25,900 "
Tinbars	...	...	...	35,100	49,200 "
Sheets (black)	...	...	...	15,000	10,300 "
Sheets (galvanised)	...	...	...	10,700	13,400 "
Blooms and billets (for sale)	...	...	...	200	500 "
Total				303,300	360,100 "

The rate of increase of output in recent years may be judged by the fact that in the official year (April 1st to March 31st) 1923-24, the output of rolled steel was about 163,000 tons and in 1924-25 about 248,000 tons. In 1926 the total production of steel ingots by the Tata Iron and Steel Company was nearly 522,000 tons.

Tinplate Company of India. Although this Company does not produce steel, it may suitably be mentioned here, as the manufacture of tinplate is usually regarded as a branch of the steel industry. The Company was formed in 1920 by the Burmah Oil Company and the Tata Iron and Steel Company for the manufacture of tinplate from steel to be made by the latter firm. The

Oil Company is the largest consumer of tinplates in India and entered into an agreement with the Tinplate Company to purchase annually all the "prime" plates made from 35,000 tons of tinbar. The works were erected in 1921 and 1922 at Golmuri, about three miles from Jamshedpur. The first tinplate was rolled in December, 1922. In 1923 the Company's total production of tinplate was over 9,000 tons, in 1924 over 20,000 tons, in 1925 over 29,000 tons and in 1926 34,400 tons. The plant has been fully described* by Mr. F. L. Estep, of Messrs. Perin and Marshall, the consulting engineers to the scheme. The most interesting feature not of a specially technical nature is the thoroughness with which provision has been made to counteract the difficulties of performing such hot work as sheet-rolling in a tropical climate. The buildings are large and high; the iron floor plates round the mills have projecting bosses underneath which stand in running water; the mill furnaces have water-cooled fronts and are hooded; air, cooled by washing, is supplied through iron elbows at convenient heights at several points round each mill where the men usually stand; and the doubling of the packs, one of the most arduous tasks, is done mechanically instead of by hand. These special precautions have been successful in enabling production to be continued without interruption even during the hot season.

Indian Steel Wire Products, Ltd. This Company also erected works close to Jamshedpur in 1921 and 1922, the original intention having been to convert wire rod made by Messrs. Tata into plain or galvanised wire, wire nails and stranded fencing wire. Messrs. Tata having found that wire rod cannot be rolled economically on their existing mills, the Wire Company has up to the present worked on rods imported from the Continent. The output has been very small. The Company has always been short of working capital and negotiations which may affect its future are understood to be proceeding.

DEMAND FOR IRON AND STEEL IN INDIA.

The natural resources, *i.e.*, mineral deposits, of India for the manufacture of iron and steel have been very briefly described and the existing industrial resources, namely, the manufacturing plants for utilising those minerals, have been indicated. It will now be convenient to discuss the extent of the demand in India before any opinion is formulated about the future growth of the industry.

Pig Iron and Iron Castings. As the imports of pig iron during the last three years have averaged little over 6,000 tons a year, it may safely be assumed that they were of special qualities, *e.g.*, low-phosphorus hematite iron, principally used for the small steel-making plants at Ajmer and Ishapore. The importation of foundry iron has practically ceased. Iron castings in the form of machinery are naturally imported in large quantities, but as the cost of the iron is in almost all cases a relatively small proportion of the cost of the

**Year Book, American Iron and Steel Institute* (1924), p. 308.

machine, these may be left out of account. The only form of iron castings imported which may be regarded as entering a market which would be a natural outlet for Indian iron are cast iron pipes and railway chairs and sleepers. The annual import of the former has now fallen to less than 15,000 tons (three year average), while the import of cast iron sleepers is probably quite small, but no separate statistics are available.

No official statistics are prepared of the consumption of pig iron or the production of iron castings in India. The sales of the iron-making firms indicate that for the last three years the consumption at foundries not attached to the blast-furnace plants has not exceeded 100,000 tons annually. Owing largely to an increase in the demand for cast iron sleepers, the consumption in 1927 is expected to be higher and it is probable that the total production of iron castings in India in 1927 (including those made in foundries attached to the blast furnace plants) will consume between 200,000 and 250,000 tons of pig-iron.

There are two other outlets for Indian pig iron, namely, the manufacture of steel and exportation to other countries. The amount of pig iron required for the steel furnaces in India in 1926 was probably a little over 500,000 tons. It will thus be seen that more than half the Indian pig iron is consumed in this way. But this consumption, together with that of the iron foundries, still leaves a substantial surplus, which is available for export. Owing to the low cost of production of pig iron in India the makers have had no difficulty in recent years in finding overseas markets, presumably at remunerative prices, for their surplus production. The exports of pig iron from India for the last four calendar years are shown in the following table :—

1923	181,500 tons
1924	271,000 „
1925	402,000 „
1926	315,000 „

In 1925 the United States took about 45 per cent. of the total exports and Japan about 35 per cent., but in 1926 the positions were reversed, Japan taking over 75 per cent. of the total and the United States about 13 per cent.

It is thus clear that India is not merely self-supporting in respect of pig iron, but that it has become an important competitor in the world's export market.

Steel. Although India has so successfully made the first step in utilising its enormous resources of iron ore by making itself independent of external supplies of pig iron, it still remains a very large importer of steel. In spite of the rapid growth of the output of Indian steel during the last few years, India still offers to the steel manufacturer in Europe one of the largest export markets in the world. In the following table the imports and the Indian production are shown. As there are practically no true exports of Indian steel or re-exports of imported steel, the imports and the production together show

the total consumption of the country. The imports definitely classified as iron in the Indian trade returns and also cast pipes, are excluded from the figures. Certain forms of iron castings and of wrought iron cannot be completely separated from steel in the import figures, but any error thus caused is probably less than 3 per cent. of the total. The import figures do not include steel in the form of hardware, rolling-stock, machinery, etc.

CONSUMPTION OF STEEL IN INDIA.

Year.			Imports.	Indian Production.*	Total.	
1911-12	...	...	855,000	10,000 (approx.)	865,000	tons
1912-13	...	...	923,000	25,000	948,000	„
1913-14	...	...	1,206,000	55,000	1,261,000	„
Average			995,000	30,000	1,025,000	„
Calendar Year.						
1924	...	...	982,000	240,000	1,222,000	„
1925	...	...	837,000	310,000	1,147,000	„
1926	...	...	998,000	360,000	1,358,000	„
Average			939,000	303,000	1,242,000	„

The figures show that India's demand for steel has now passed even the demand of the previous "record" year, 1913-14, and that in spite of the large increase in the internal production the average importation of the last three years is only about 5 per cent. less than the average of the three years immediately preceding the War.

KINDS OF STEEL CONSUMED.

The information available does not enable a very exact classification to be made on simple lines. The following figures are, therefore, only approximate. They represent estimates of the total consumption (*i.e.*, imports plus internal production) of the main kinds of steel used in India during the last two calendar years:—

	1925.	1926.	
Galvanised sheets	265,000	320,000	tons
Bars (ordinary qualities)	170,000	235,000	„
Rails and fishplates	Nearly 170,000	Over 190,000	„
Angles, beams, channels, etc., and bridgework and other structures	180,000	180,000	„
Plates	65,000	65,000	„
Tin plate	59,000	58,000	„
Sheets (not galvanised or tinned)	60,000	50,000	„
Sleepers	Over 30,000	40,000	„
Hoops and strips	39,000	38,000	„

*For correlation with the imports, the figures for Indian production relate to rolled steel—not to ingots—and include finished tinplate, but not the tin bar from which the tinplate is made.

As will be expected, the proportions vary from year to year. The consumption of galvanised sheet has been abnormally high during the last two years, whilst that of sleepers was relatively low. But the indication given by the above figures, namely, that galvanised sheets, bars, rails and structural sections account for about two thirds of the total steel consumption, is generally correct.

It will be of interest to consider the sources of the imports into India. For this purpose the imports for the official years (April 1st to March 31st) must be studied, as the returns for the calendar years are not completely classified in this way :—

SOURCES OF STEEL IMPORTED INTO INDIA.
(Thousands of Tons.)

Year.	United Kingdom.	Belgium.	Germany.	France.	Other.	Total Non-British.
1911-12	... 598	89	131	3	35	258
1912-13	... 659	107	119	2	36	264
1913-14	... 817	171	195	2	21	387
1924-25	... 494	275	87	16	51	429
1925-26	... 528	264	72	46	50	432

The percentage of imports from Great Britain to the total imports has fallen from about 70 per cent. in the pre-war period to less than 55 per cent. in the last two years. The imports from Belgium have increased to a very notable extent, while those from Germany have fallen. Imports from France did not begin to be substantial until 1925. During the last few years the British manufacturer has lost ground not only to the Indian manufacturer, which was inevitable, but also to the Continental manufacturer.

The galvanised sheets used in India are almost entirely of British origin, the imports of these sheets forming more than half the total imports from the United Kingdom. Rails are now mainly Indian and bars mainly Continental, while structural sections and plates are still drawn to an important extent from each of the three sources, namely, India, the United Kingdom and the Continent.

GENERAL CONDITIONS AFFECTING THE INDUSTRY.

Although the Indian iron and steel industry has the advantage of possessing very large deposits of rich ore which can be worked at a low cost and also large deposits of useful coking coal within reasonable distance of the ore, it has certain disadvantages which, in the early stages of development at least, limit its capacity to hold its own against European competition. The most obvious drawback—and that a permanent one—is the climate. In the iron-making districts, the temperature is regularly much higher during April, May and June, and frequently also in March and October, than at any

time of the year in the corresponding districts of Europe. During each hot season the temperature frequently exceeds 110° F. and at Jamshedpur it has occasionally been over 120° F. During July, August and September also the temperature is high by comparison with European standards and the atmosphere is also excessively moist. In such circumstances, iron and steel-making is very arduous and special provision is necessary either in the lay-out of the works or in the details of the equipment, to reduce the climatic discomfort as far as possible.

A further disadvantage to the Indian manufacturer lies in the fact that owing to the location of the ore and the coal his works must be built in an undeveloped district, where he must construct all the houses, schools, hospitals, markets, roads, etc., and provide the water supply and drainage, from his own resources. While the net annual cost of this provision may, when the new town is well established, be no greater than annual payment for local rates and similar charges in Western Europe for a works of the same kind, the initial capital burden and the demand on the time and energy of the management form a distinct handicap in the early stages of a new undertaking.

India possesses no heavy mechanical engineering industry of the kind from which supplies of steel-works plant and machinery can be drawn. For all his main requirements the manufacturer is, therefore, dependent on importation, which involves a double burden in that he must hold large reserves against breakdowns, and that the additional freight, customs duty and associated charges involve him in higher cost than his competitors in the chief steel-making countries. He must also maintain larger repair shops than are necessary in Europe.

Up to the present, the main handicap of the Indian manufacturer in this industry has been the lack of skilled labour. The processes involved are new to the country, and as each new works has started it has found itself unable to draw more than a very small proportion of its labour from existing reserves. Most of the men employed have, indeed, had no previous experience of work in factories, and as the standard of physique in India is lower than that in Europe, a satisfactory labour staff capable of sustaining the heavy work of iron and steel manufacture in such a climate can be collected only slowly. To this difficulty must be added the reluctance of many of the Indian workmen to adopt factory work as a permanent means of livelihood. Up to the present it has been inevitable (and it will probably remain so for some years) that the assembling of satisfactory labour and its training to a reasonable degree of efficiency should be a much slower process than in Europe, and it is probable that the number of men required in India to produce a given output will remain much higher than in Western countries for many years.

It will be obvious that in the early stages of each undertaking the managing staff and almost all the skilled workmen in the producing departments, *i.e.*, about the furnaces and mills, had to be brought from outside—mainly from

Europe, but partly from America. Skilled men will naturally not leave their own countries to perform such work in a climate like that of India except for the attraction of higher pay than they would receive in their own country, or than would suffice for equally efficient Indians, when such are available. There is thus a strong inducement for each firm to facilitate the training of educated Indians for skilled and responsible work. Until recently this was done chiefly by giving training posts as assistants, foremen, etc., to Indians, who after some scientific training in India had passed through a technical course in one of the Western countries and in most cases had obtained some works experience there. A few years ago, however, the Tata Iron and Steel Company decided to supplement this source of supply by establishing in Jamshedpur a Technical Institute in which Indians with an Intermediate Science (or higher) degree and of good physique could be specially trained. The course consists of alternate fortnights in the laboratories and lecture-rooms and in work as apprentices in the different producing departments of the works. The applications for admission are so numerous that the Company is able to make a most rigorous selection, and the subsequent work of the students who have completed the course indicates that the scheme will be very successful. The students come mainly from Bihar, Bengal, the Punjab and Madras, in the order named.

TARIFF PROTECTION.

A development connected with the iron and steel industry in India which has attracted much attention during the last few years is the introduction of protective duties and bounties for the assistance of the steel industry. When the slump occurred in the world's steel trade in 1921, the Tata Iron and Steel Company, which was then in the process of erecting very large extensions of its works, was badly hit, and by 1923 its position had become one of great difficulty. In July, 1923, the Indian Tariff Board, under the presidency of Sir (then Mr.) George Rainy, was formed in accordance with the recently adopted policy of "discriminating" protection and its first task was to consider an application for protection of the steel industry. Revenue duties have for many years formed an important part of the finance of the Government of India, and in 1923 the duty on imported steel was 10 per cent. The Tariff Board found that protection was necessary and that the industry complied with the conditions laid down; and on the Board's recommendations, duties (coupled with bounties on rails and fish plates) were imposed in 1924 on the kinds of steel manufactured in India at specific rates which were equivalent to between 15 and about 30 per cent. *ad valorem*. Provision was made for a re-consideration of the amount of the duties during 1926-27, any changes to be made becoming effective on the 1st April, 1927, and it was also provided that if during the interval the prices of imported steel fell to such an extent as to make the duties ineffective additional pro-

tection could be granted. Prices did so fall and the necessary additional protection was given by way of bounties on the total ingot production at rates which were equivalent initially to Rs. 14, and later to Rs. 8 4 per ton of ingots.

During 1926 the statutory inquiry was held by the Tariff Board, now under the presidency of Mr. P. P. Ginwala, to consider whether the continuance of protection was necessary and, if so, what the measure and form of the protection should be. The Board's report was published on the 13th January, 1927, and a Government Bill to give effect to the recommendations (with certain slight changes) was introduced in the Legislative Assembly on the 26th day of the same month. As this paper is being written at a time when the Bill is still before the Indian Legislature, a very brief summary of the proposals only is given. The continuance of protection has been found to be necessary, but in substantially reduced degree. It is proposed that no bounties be given and that the duties now to be fixed shall continue for seven years. On fishplates and steel sleepers duties of not more than 10 per cent. are required; the duties on rails and on galvanised sheets are equivalent to about 12½ per cent. and the duty on tinplate to about 15 per cent. As regards the other protected articles, namely, structural sections, bars, plates and black sheets, it is proposed that the duties on non-British imports shall be higher than those on British. The duties on the latter vary between about 17 and 24 per cent., all (except that on black sheets) being less, in rupees per ton, than the existing duties. The duties on non-British steel of these kinds vary between about 35 and 40 per cent. It is also proposed that the duty on fabricated steel, which in 1924 was fixed at 25 per cent. *ad valorem*, should now be lowered to 17 per cent., with, however, additional duties on material of non-British manufacture.

It should, perhaps, be made clear that no protection, whether by duty or by bounty, has been claimed for or given to pig iron and iron castings, either in the 1924 Act or in the present Bill. Protective duties apply, however, to certain forms of wrought iron of common quality which might be substituted to some extent for steel if there was much difference in the duties.

FUTURE DEVELOPMENTS.

It has been seen that in 1926 India produced 900,000 tons of pig iron, of which over one-third was exported, while the imports were only a few thousand tons, and that the production of steel ingots and castings was about 540,000 tons, of which none was exported, while about one million tons of rolled steel were imported. Some indication of the trend of development may be of interest.

Pig-Iron. Of the three outlets for pig iron, namely, the production of iron castings, exportation and the manufacture of steel, the first cannot be expected to expand rapidly, nor can a large increase in the exports during

the next two or three years be assumed with safety. The demand for pig iron in the East is small, apart from the requirements of Japan, and large supplies to Europe or North America are not possible economically, except when sea freights are low. Thus, while both these outlets for Indian iron may be expected to expand, it is to be expected that in the future, as in the past few years, the growth of the output will depend mainly on that of the manufacture of steel. As regards capacity, the Bengal Iron Company could probably produce 200,000 tons per annum, the two furnaces of the Indian Iron and Steel Company about 350,000 tons and the five furnaces of the Tata Company about 900,000 tons when ample blowing power is available. The total production in India during 1927 will probably be over one million tons unless the demand is unexpectedly restricted.

Steel. The production in 1927 will probably be rather over 600,000 tons of ingots, equivalent to about 420,000 tons of rolled steel, which may be regarded as almost the limit of capacity of the existing plant in India unless unusual circumstances led to the full operation of the small plants at Ishapore and Jamalpur. The Tata Iron and Steel Company, however, contemplates making additions to its plant, which will in a few years bring its capacity up to about 600,000 tons of rolled steel. It is understood that the Indian Iron and Steel Company is considering the advisability of adding steel-making plant to its existing blast furnace plant and that the United Steel Corporation of Asia (a company which was formed in 1920, but which has not yet got beyond the stage of securing leases of the necessary mineral deposits) is also re-examining its scheme for erecting a large steel works near the Singhbhum ore field.

While the rate of growth of steel consumption in India cannot be foreseen with any certainty, it is probable that a substantial part of the extra output at Jamshedpur will be absorbed by additional demand. But there is no reason to expect that India would be able to absorb the output of two more large steel works when they reach full production, if the erection of both were commenced during the next year or two, although there is a reasonably good field for one additional plant. So long as the Indian steel industry must be based on Singhbhum ore and the coal of Bengal and Bihar, it is fallacious to expect that Indian steel can completely replace imports in places like Karachi, Southern India and Burma until the costs of production have been brought down practically to European levels, for the sea freights from Europe to those parts of India are lower than the internal freights from either the ore or the coalfield. Moreover, the figures of total imports include what are, in the aggregate, considerable quantities of steel products which, owing to the smallness of the present demand for each individual product, cannot yet be economically made in the country. It is doubtful whether, outside Sind, the extreme South of India and Burma, the total Indian demand for the kinds of steel which might economically be manufactured exceeded one million tons in 1926.

The conclusion may safely be drawn that the Indian steel industry will develop, perhaps fairly rapidly, during the next few years, and that for some time afterwards its growth will depend mainly on the rate at which the demand increases. But for the next few years imports will not diminish to a great extent, unless the consumption declines or remains stationary; and even in later years there will remain an important market in India for certain kinds of steel.

The author is much indebted for the supply of recent statistics and other information to the officers of each of the companies mentioned in this paper, of the East Indian and the Bombay, Baroda and Central India Railways, and of the Master-General of Supply Branch, Army Headquarters, and to the Dewan of Mysore.

DISCUSSION.

THE CHAIRMAN said that he was sure that, after what the author had said, no surprise would be expressed if, to those who knew India twenty or more years ago, the story that had been told was what the evening papers would call dramatic. It was less than twenty years ago when Mr. Weld and he went to select a site for the projected Tata Iron and Steel Works. In those days there were five or six small huts, and the only industry that appeared to flourish was cock-fighting, in a jungle now displaced by the town of Jamshedpur, of 100,000 inhabitants. There has been always something romantic about the iron and steel industry in India, because India had had a reputation for the quality of its steel since long before the Christian era. The high quality of Indian steel gave rise to the impression that Indian iron-ores were of very pure standard, and the fact that primitive workers in iron, and in some places in steel, were found scattered over practically every district away from the great alluvial belt had given rise to the general impression that India must be also rich in iron-ore, as well as having raw material pure in quality. It was only about 100 years ago that Josiah Heath left the Madras Civil Service as Deputy Commercial Resident, or what would now be called a Sub-Collector, in order that he might test his faith in Indian minerals, and it was in 1830 that he started his first blast furnace in the South Arcot district, a blast furnace which was then regarded as on a commercial scale, the local fuel at that time being, necessarily, charcoal. The early attempts to make pig iron, some of which was sent to England for conversion into steel, and was actually used in the construction of the Menai tubular bridge, led to a series of disasters that came finally to an end in 1867. The next attempt was made on the Bengal coalfields in 1875. The intention then was to use coke for fuel and clay iron-stone, which was found associated with the coal on the coalfields. That led again to a series of failures until the works were taken over by Messrs. Martin & Company in 1899, and, after one little flutter with steel, they settled down to the manufacture of pig iron. The ambition to make steel on a large scale was the ideal of the late Jamsetji Tata, and that object, as were so many other of his remarkable enterprises, was as much due to patriotism as to commercialism. Mr. Tata died in 1904, and was unable to see either the steel project started or his hydro-electric scheme, but his sons and the members of his firm carried his projects to a successful issue. As difficulties arose—and serious difficulties did arise time after time—they were faced and overcome by an intense faith in Mr. Tata's ideals, and an almost religious devotion to the

memory of one who was undoubtedly a great man.' Fortunately, the faith which inspired Mr. Tata's successors was not merely idealistic; they inherited his method, his indomitable spirit, his readiness to face facts, and his rigid honesty in commercial transactions. It was his (the Chairman's) accidental privilege, as a technical adviser of the Government when the project was first started, to see the inside of almost every stage in the development and right through it was quite obvious that the requirements of commercial necessity were continually tinged with an inspiration of public spirit and duty. Everybody knew there was far less risk in the making of pig iron than in undertaking the much more complicated stage of converting it into marketable steel. There was also for the capital expenditure incurred in pig iron a far better margin of profit, or certainly there would have been in India. It would have been relatively simple, therefore, if the Tata Company had decided to limit their enterprise in the first instance to pig iron and then, after gaining experience, to risk the next big step; but Mr. Tata knew that it was steel, and nothing short of steel, that was necessary for India's industrial development; that was his ideal, and to that ideal his successors were faithful, although they knew quite well that in making plans to undertake in the initial stage, not only pig iron, but steel, they were multiplying their risks and not merely adding to them. He would repeat that their object was as much patriotic as it was commercial. The Company was registered first in 1907, but the first pig iron was not produced until December, 1911; and, as the steel works were erected side by side with the blast furnaces, the first steel was produced early in 1912, and then came the usual crop of troubles. Luckily, for India at any rate, there were two years to spare before the war broke out, two years to get over the initial and inevitable troubles of a new enterprise. He said inevitable, because the industry was a complicated one technically, and in that case nearly every disturbing and important factor was entirely novel. They had, as the author had described, to import their technical supervisory staff, which had to work under conditions entirely unfamiliar. They had absolutely untrained labour in every department, not only untrained in iron and steel making, but inexperienced also in any form of factory life. They had a coke to deal with with an ash percentage from which an English steelmaker would have turned with disgust. They had a climate to work in which, apart from the disadvantage of a high temperature in hot weather, had a humid monsoon for a period of three or four months, which must have had a serious effect on the operations of the blast furnaces, if not on the steel works. Then they had the necessity of constructing an entirely new town, with all its accessories of sanitation, drainage, water supply, schools, hospitals, roads, and so forth in an absolutely wild jungle; and he would say, lastly, what might have been a much more difficult condition, certainly one of those that nobody could estimate the value of, they had a Board of Directors with no experience of either iron or steel; they were entering a market against expert sellers, and they had the knowledge that no one before had succeeded in making steel in India. Much worse, they had a number of sympathetic friends ready to say, "I told you so!" It required some pluck to face the risks, and he was perfectly sure that English iron and steel masters, who were accustomed to facing and overcoming difficulties, would admire them for the courage they showed, and would congratulate them on the success which followed. But for their enterprise the country would have been seriously embarrassed when the war came in 1914. The supplies of imported steel were cut off from India, first by the necessity of devoting home materials to the war zone in Europe, and secondly by the effect of submarines; but, from the commencement of the war to the end of 1918 the Company supplied the Government with just a little under 300,000 tons of steel. The

quantity supplied from their works amounted to about 70 or 80 per cent. of the total output. During the latter half of 1918 the Government were able to take as much as 90 per cent., and in one month 97 per cent. He thought very few people realised that the military railways by which the Mesopotamian campaign was carried on, and even the line from Egypt by which Lord Allenby made his successful attack on Palestine, were constructed of steel from the Tata works.

There were two points he should like to make one or two comments upon. He was able to speak with some knowledge as the officer at that time responsible for the supply of munitions to the armies east of Suez. The rail steel supplied by the Tata works conformed rigidly to the British standard specification. The metallurgical inspector, Mr. Mather's predecessor, saw that nothing but British steel standard would be accepted, whilst the price accepted by the firm, not on compulsion, but by free will, was the controlled rate of steel at that time laid down in England. Steel which was rejected by the Government Inspector, because it did not come up to the standard specification, could be sold—and he believed was sold—in the open market in India at prices which varied from twice to four times the price paid by the Government for steel that was accepted. Yet the General Manager of the works was the only one he ever heard grumble at the rigidity of the Government's tests. No allowance was made in the price laid down—150 rupees a ton when steel at that time was £10 a ton here—for freight or transport charges or dues of any sort on steel imported into India, and that was to some extent not in accordance with their original contract. According to the original contract made between the Company and the Government they had to supply 20,000 tons of steel rails at competitive prices, the prices of imported steel as delivered at Indian ports. It would have been impossible to have obtained controlled steel from England at the rates which the Company were paid during the war, because the price paid to them had no regard to freight at all; they were actually paid the English control rates. Another thing worth mentioning was a small item, also often forgotten. At the beginning of the war they had two blast furnaces and four steel furnaces, and the steel furnaces could not absorb the full capacity of the blast furnaces; the Company had, therefore, a surplus of pig iron which could have been sold at a great profit; but in order to meet the increased Government demand for steel, they put up two more steel furnaces, and so absorbed their own pig iron. He should like to go back to the original contract, about which more stories had been told than about the war. It was generally supposed that the Government went out of its way to support and pamper the new industry in India. The actual amount of support given was that the Government made an offer to take 20,000 tons of steel rails at the price of steel competitively delivered at an Indian port; they also authorised the Bengal-Nagpur railway to construct a line from the ore fields to the works. No other conditions were granted. Those two conditions meant that the Government had to make up its mind whether the new enterprise was going to be a success or not; that was to say, whether it was worth while ending their contracts in England for steel rails in order to place a contract in India—whether it would be worth while to construct a new line a little over 40 miles in a difficult country through an area which would create little other traffic worth considering. The result had been that the increase of ton-miles for the Bengal Nagpur system at the beginning of the war was something like 150 per cent., due to the raw materials and products of the Tata Steelworks. There was no doubt, therefore, that as a commercial proposition the Government were wise in also showing some patriotism. He should like to say how much people in India and people at home who had had commercial dealings with the great Company regretted the loss by death of Mr. R. D. Tata last year. Everyone who

came into contact with him felt that they were dealing with a straight and honest commercial man.

There was always anxiety to know how the Indian Legislature when they got their fiscal independence, would deal with the matter of tariffs. One was always naturally curious to know how the new Indian Legislature would play with the new toy of tariff independence, and he believed Sir William Larke would agree that they had now treated the matter as a protective tariff in a commercial and not in a political way. They had not put a protective tariff on an industry which was inefficient, and could not respond to the stimulating medicine of protection. They had reduced the tariff when they found it was no longer necessary. The new discriminating schedule passed in the previous week was not purely a political concession to Imperial interests, but he considered it to be one of the best bits of commercial sense they had shown in dealing with the tariff. They had now discriminated in favour of British steel, and anybody who had seen samples of steel from elsewhere would realise that it was commercial good sense that had made them so discriminate.

SIR ATUL C. CHATTERJEE, K.C.I.E. (High Commissioner for India), expressed his gratitude to the author for his extremely informing paper. He thought everyone would agree that the author had marshalled his facts in a very clear manner, and had brought out all the salient points with regard to the development of the iron and steel industry in India in recent years. He thought the meeting was also fortunate in having as Chairman Sir Thomas Holland, who was second only to the late Mr. Jamsetji Tata in deserving credit for the recent progress of the iron and steel industry in India.

He desired to draw attention to one or two aspects of the question which had not been treated by Sir Thomas Holland. The development of the iron and steel industry in India was of very profound importance to the country, not merely from the point of view of the industrial development of India, but from the point of view of the general development of the country. Only a few days ago he was looking at some writing of his friend, Mr. W. H. Moreland, regarding the economic condition of India in the Mughal period, and Mr. Moreland, who was an authority on such subjects, had very clearly brought out the fact that until quite recent times agricultural implements in use in India had been practically the same as those which were used three or four hundred years ago, and that the main distinguishing characteristic of Indian agricultural implements as compared with those in use in western countries was the economy of iron. That had been really due throughout the centuries to the fact that the manufacture of iron and steel had been an extremely costly process in India. The manufacture of iron was limited by the supply of charcoal; as soon as the local supply of wood failed, the industry had to move to a new site, with the result that agricultural implements in India had been always of a more or less primitive type. There was hope now that with the greater development of agriculture to which they all looked forward, not only as the result of the Agricultural Commission now working in India, but also on account of the general development of the country, the implements used would be very greatly improved and there would be a very much larger use of iron and steel in agriculture. That factor had to be taken into account in considering the future consumption of steel and iron in India. The author suggested that there was not likely to be much scope for more than one large iron and steel works in India in the near future. He did not wish to dispute that opinion, but in taking a longer view, he thought there was plenty of scope for a very much greater consumption of iron and steel

in India per head than at present. He had tried that morning to compare the average consumption of iron and steel per head in India with the average consumption in western countries. He did not know whether the figures he had obtained were absolutely correct or not, but it appeared to him that whereas in the United Kingdom the total consumption of iron and steel averaged within the last three years something between 12 and 15 million tons, with a population of only about 50 millions, in India, with a population of about 320 millions, the average consumption could not be more than 2 or 3 millions at the outside. He thought there was a similar disparity between the consumption in India and the consumption in European countries. That would indicate the low consumption which at present prevailed in India on account of the primitive conditions there not only with regard to agriculture, but with regard to building, communications, and so forth. He did not say that much had not been done in recent years, but he thought there was enormous room for improvement in all those matters. He hoped that in the not very far distant future Indian agriculture would demand very much more machinery, that the mileage of Indian railways which was already as great as that of any western country excepting America and Great Britain, would be greatly increased; that the roads would be very much improved; that there would be better bridges requiring the use of more steel, and that the people would live in better houses, which would also mean the increased use of iron and steel. Irrigation works also would bring into use very much larger areas of land and that would also mean the greater use of iron and steel. He hoped that in future all manufacturers of steel in India and in England would bear in mind the fact of the greatly increased consumption that was likely to arise with the development of India.

Another point not mentioned was that not only in the Tata works, but in the Bengal Iron Works, the labour conditions were excellent compared with the labour conditions in many factories and works in India. He had not much personal knowledge of the works of the Indian Iron and Steel Company. He thought great credit was due to the industry in India for providing in an exemplary manner good conditions for their workers. They had been very wise, because unless there was efficient and contented labour, it was hopeless to try to establish an Indian industry on a sound basis.

With regard to recent tariff history in India, he was a member of the Government which introduced the new discriminating tariffs, and he thought the policy which was adopted then had been fully justified. It was a remarkable achievement that the tariffs which were then imposed had been reduced very considerably at the very first revision after three years. That policy was not established in any spirit of antagonism to British industry, or to any industry outside India, but it was felt that it was most necessary to establish a steel industry in India for the purpose of Imperial defence and protection, if for nothing else. Any other policy would have been most dangerous.

SIR WILLIAM LARKE, K.B.E. (Director of the National Federation of Iron and Steel Manufacturers) associated himself with the thanks given to the author for his extremely valuable record of the present development of the iron and steel industry in India. The British iron and steel industry had adopted as a definite policy the policy of co-operation with the Indian steel industry, and as an industry they fully realised that the findings of the Tariff Board, which had resulted in the adoption by the Government of India of differential duties, involving higher duties on continental imports, were not the outcome of political considerations in any sense nor of a desire to adopt a policy of Imperial preference, but were based

absolutely impartially on the economic interests of India alone. The reason no doubt was that the effect of depreciated exchanges on the Continent had resulted in an entirely artificial price level in the exports from continental countries to India, and did, in fact, in part defeat the economic policy of India in regard to the tariff on imports. Those conditions did not obtain in this country, which was on a gold basis, and he was confident that the recognised quality of the British product was an important factor in causing the Tariff Board to arrive at its decision. The economic and industrial development of India was now proceeding very rapidly, and its successful progress depended entirely upon the adoption of a wise economic policy and on obtaining the materials required for this development at the lowest possible cost to the consumer, and so the tariff policy recently adopted was in the best interests of India. British manufacturers were thankful to think that the interests of India and those of their own industry in this country were parallel and common, and he believed that they must long remain so. The present age in the West was one of iron and steel, and India was rapidly developing towards the same condition. The demand for iron and steel in India must grow ultimately to an immense figure, in view of the enormous population, the progress of industrial development and the gradual improvement in the standard of life.

He thought the author was a little hard on wrought iron when he rather gave the impression that wrought iron had almost ceased to be useful as a material. Wrought iron had a very important part to play in the industrial economy of all countries because of its peculiar qualities in resisting shock and its non-corrodibility. One of the finest examples of wrought iron was the Delhi Column, which consisted of $6\frac{1}{2}$ tons of wrought iron, and had been exposed to the atmosphere for many centuries, with little or no signs of corrosion. He thought it was historically correct to say that the art of working iron and steel, if it did not originate in India, was very highly developed in India long before the Christian era. He believed the steel from which the famous legendary swords of ancient times were made was certainly produced in India; the famous Damascus sword blades were made from an Indian steel which was brought to Damascus by merchants. In those days the word "steel" was not generally used, but there was no doubt that "wootz" was in fact steel. Most of the iron was produced in primitive furnaces, in lumps of only two or three pounds in weight, and was then sealed in small boxes and put into charcoal furnaces and converted into steel by the cementation process used in Sheffield to-day in producing high-grade steel. The swords had a very remarkable temper and fine cutting edge, and they could be bent double from tip to hilt. Practically the whole of the Swedish iron industry to-day was based on charcoal, and always had been, and Sweden produced some of the purest iron, which was the basis of many of the finest steels produced in Sheffield. In Great Britain, in Cumberland, there was one charcoal furnace which was run for about three months a year for producing a small quantity of iron used for highly special purposes. While the smelting and working of iron might have had its birth in Asia, the birth-place of the iron and steel industry on a large scale was in this country in 1747.

With regard to the progress of the Tata Company, there had been a very large export of pig iron to Japan, and he had been very much interested to find from the reports that the Japanese found that the importation of Indian pig iron was causing the Japanese a great deal of embarrassment on account of the low price, and the Japanese ironmasters had now sent a mission to Calcutta to negotiate with the Indian ironmasters, begging them to raise the price of pig iron delivered in Japan. That was an important testimony to the efficient production of Indian pig iron. India was able to export pig iron to the United States, and in 1925 exported 170,000

tons. He believed the principal market in the United States was on the Pacific coast. This was quite a substantial business to do with a country which was certainly an exemplar of the policy of protection.

With regard to mechanical doubling in tin-plate works, he had only seen that once, and he should like to know whether that plant was invented in India or America, or was it British in origin? He should like to ask the author whether he thought the Indians had a sufficiently strong physique to be able to undertake steel-making and rolling in all its processes. With regard to the high ash content in the coal, India had not found the need of coal washing, and perhaps that process would be too costly, but he should like to know whether it had been considered.

MR. GEORGE PILCHER, M.P., said he had been very much impressed by the statement of Sir Charles Innes in introducing the forerunner of the present tariff legislation, when he said that if the masses of the Indian consumers could hear and realise what he was doing he would probably not be engaged in doing it at all, and he (the speaker) and his colleagues had felt it necessary to put the consumers' case as strongly as they possibly could while the project was in the development stage. He was still greatly impressed by the consumers' position, and he should have liked to have heard something about the real cost to the Indian consumer. Everyone realised that India had the ore, the coal and the flux side by side, and, if willing to make the sacrifice, could create a great iron and steel industry. The only consideration to which perhaps sufficient attention had not been given was in regard to the cost of creating it, and the cost to the Indian consumer at a time when all the evidence pointed to a largely increased consumption of iron and steel. At that time he had thought that India should spend £20,000,000 a year in extending her railway connections. India was a great country, containing one-fifth of the human race. His colleagues and himself realised the potentialities of railway development and wanted to see the programme go on faster, and they could not help but wonder what would be the effect of an additional 10% or 20% *ad valorem* on the cost of railway material. There was also a very strong desire on their part to see iron and steel used largely in agricultural development. He had advocated in the House of Commons the dealing with that potential demand in the agricultural sphere, for ploughs, pumping plant, and so on. The increased cost of steel must presumably increase the cost of those things to the consumer and retard the rate at which he could acquire them. He put the consumer's case as strongly as possible and left it to the Imperial Assembly to deal with it. He should very much like to hear an estimate of the cost to the consumer in terms of sterling per annum. He was glad to hear of the progress of the experiment *quâ* experiment, and should like to pay his tribute to the amazing courage of Mr. Jamsetji Tata: There was nothing more impressive in the East as an expression of the modern mechanical and scientific mind than the Tata Works, which he understood were now producing 420,000 tons of steel a year, and were, he believed, to be further extended. He hoped the great project would achieve the success which it deserved.

MR. JAMES CAWSON said he wished to compliment the author on the extremely interesting and lucid lecture he had given. The author had referred to the estimated amount of three thousand million tons of iron ore, and had also said that it was considered inadvisable to utilise that ore unless it gave a yield of 60 per cent. How was it that they had to discard all the ore that did not contain 60 per cent.?

MADAM F. A. DE SILVA (Anglo-American Steel Co., Ltd.) said she was much indebted to the author for his lecture, as she had learned a great deal and it had given

her great encouragement, as she was interested in the ores of India in connection with the production of steel.

A hearty vote of thanks was accorded to the author for his paper.

MR. MATHER, in reply, said how completely he shared the admiration of Sir Thomas Holland for the courage and enterprise shown by the founders of the great undertaking at Jamshedpur. He went on to agree with Sir Atul Chatterjee that any really large development of the steel industry in India must depend mainly on the general economic development of the country, which must be based on the prosperity of agriculture. While there could be little doubt that in a not very distant future there would be room in India for two or more large new steel works, he still thought that present circumstances did not warrant the erection of more than one new works during the next two or three years.

The interesting and authoritative remarks of Sir William Larke on the subject of co-operation would be appreciated in India. As the result of hard struggles, the Indian steel industry was winning its "place in the sun," and the wide recognition of this fact would be mutually helpful both to the new industry there and to the older industry in England and elsewhere. It was far from his (the lecturer's) intention to suggest that wrought iron was ceasing to be useful, but the fact that the output of the material was declining in the older countries, apart from other considerations, made it very improbable that this branch of the industry would be undertaken in India. It was interesting to note that the Indian pig iron exported to the United States went mainly to the Atlantic coast, where it competed actively with European pig iron; in 1925-26 less than 5 per cent. of the Indian iron sent to the States was shipped to ports on the Pacific. The sheet-doubling machines used by the Tinplate Company of India were of American design and manufacture. While it could hardly be said that the physique of Indian workmen generally was suitable for the heavy operations of steel making and rolling, it had been possible, by a process of selection and elimination, to assemble staffs of men able to cope with the work, and there was no reason to believe that the sources of supply of such men were exhausted. There was now no manual operation in the industry in India which was not being conducted by Indian workmen. The possibilities of coal washing for reduction of the ash in Indian coal had been carefully explored. The ash was in an unusually fine state of division, and up to the present none of the processes which were so useful in Europe had proved themselves successful in dealing with the special problem in India.

Mr. Pilcher's question about the burden imposed by the protection policy on the consumer in India was one to which no very definite answer could be given, as any estimate must necessarily depend upon a series of assumptions. His own calculations indicated that if during the next seven years the total consumption of steel in India increased at the same rate as the output at Jamshedpur, the difference between the prices resulting from the protective duties and those resulting from revenue duties would probably average rather less than Rs. 1½ crores annually.

The question put by Mr. Cawson was evidently based on a misapprehension of what he had intended to convey. The utilisation of the Indian ore was at present confined to the rich material because it was more profitable than the use of leaner ore—not because the leaner ores could not be used in India.

The assumption underlying part of Mr. Adamson's remarks, namely, that Indian pig iron could be made for twenty shillings a ton, was incorrect. If the cost were so low, most of the disadvantages of the Indian industry would be outweighed, and there would be little need for protection for the steel industry. His (the lecturer's)

remarks in a discussion in 1925, before the Iron and Steel Institute, on the quality of Indian pig iron, showed that large outputs were being obtained from Indian blast furnaces without a sacrifice of the quality of the product. And it was similarly true that the present rate of output of steel from the plant at Jamshedpur was accompanied by the maintenance of quality, almost all the steel made complying with British Standard, or equivalent, specifications.

A vote of thanks to the Chairman concluded the meeting.

MR. E. ADAMSON (Sheffield) writes :—

Mr. Mather's outline of the present position of the iron and steel trades in India comes at an opportune moment, just after favourable fiscal arrangements have been made with this country, and his figures show that India is a long way from providing for all her iron and steel requirements.

When one of the large steel works was completed a few years ago, it was generally reported that pig iron could be made in India at the equivalent of twenty shillings per ton at the furnaces, but the author's opinion appears to be that in spite of this there are several handicaps, one of which is the lack of skilled labour.

Although many of the works are at the foothills, climatic conditions are still against active control by experienced overseers all the year round, which will naturally retard rapid developments in the industry and work against obtaining maximum outputs, for constant supervision is necessary in the manufacture of steel, especially with modern plants. Even in some parts of the U.S.A. work has to be stopped in the very hot weather.

Great Britain stands for quality of her iron and steel products. From the description of the position in India which the author has given, not only is there the risk of lack of supervision, but it is acknowledged—even in America—that large outputs do not produce the high standard aimed at by British manufacturers. This question of quality was referred to by Sir William Larke, Director of the National Federation of Iron and Steel Industries, at a recent luncheon of the American Chamber of Commerce at the Hotel Cecil, London, when he emphasised the supremacy of British Steel; and Mr. Mather, in a recent paper before the Iron and Steel Institute, acknowledged there were differences in quality of pig iron due to the methods of working the furnaces, and exactly the same applies to steel.

This statement with regard to large modern furnaces producing inferior pig iron is amply confirmed by Dr. Richard Moldenke in a recent paper before the American Institute of Mining and Metallurgical Engineers on "Foundry Pig Irons—the Necessity for Research."

It is very interesting to know that in India transport of iron and steel to the shipping ports is very high, for at one time it was freely mentioned that Indian pig iron would compete in the home markets, and certainly if the cost of producing pig iron in India is so low as 20s. per ton at furnaces, it looks as if this might have been possible, but the author's reference to the transport difficulties seems to put the matter out of court.

There is no doubt that the iron and steel produced in India will have its market probably chiefly in India, but there will continue to be—certainly for many years to come—a market for British iron and steel of standard quality, which it is acknowledged by responsible authorities cannot be equalled by works whose main object is output. This latter quality of steel drew from one well-known steel maker in America, speaking before one of the American Societies, the statement that "it is easier to make a specification meet the steel than to make the steel meet the specification," and as Britishers we should deplore the possibility of any such statement being made with regard to British steel.

CORRESPONDENCE

CHOLERA IN INDIA.

Your issue of March 18th contains a note by Sir Leonard Rogers. He says it is impossible to supply the villagers in India with pure drinking water because the cost would be many times the total income of the Government, and that I should not have made the suggestion of pure water supply if I had lived a long time in India. In reply I would say that I do not know what effect a long residence in India would have had on my intellect, but that in the few months in which I was there I had the opportunity of consulting engineers and others who had lived some years in India and I learnt from them that cholera could be easily prevented by the supply of pure drinking water, and that they put in such a supply whenever the Government allowed them some money for such a purpose and that it was only occasionally that the Government had a surplus for such work. They said the Government made it a rule never to borrow money for the purpose of sanitation, but, if that were permitted, cholera would soon be abolished. In England, of course, there is a law making it compulsory to borrow money to establish a pure water supply in every town and village.

It is my belief that the interest and redemption cost of the necessary waterworks would soon be repaid by increased revenue resulting from the improved health of the people.

As for the work of scavenging, which is the only way of abolishing the plague and some other dangerous fevers, that does not involve any heavy outlay of capital. It merely requires direction by the Government and local authorities. The present system of inoculation with so-called vaccines against plague and small-pox has been a sad failure.

ARNOLD LUPTON.

OBITUARY.

VISCOUNT COWDRAY, P.C., G.C.V.O. Lord Cowdray, who died suddenly on May 1st at Dunecht House, Aberdeenshire, in his 71st year, was born on July 15th, 1856, and was the eldest son of George Pearson, Brickendonbury, Herts. Weetman Dickinson Pearson was educated privately at Harrogate, and after serving a short apprenticeship, became in 1876 a partner in the family contracting business, which had been founded by his grandfather, Samuel Pearson. The activities of the firm had hitherto been confined to the North of England, but Weetman Pearson speedily extended the scope of the business as a result of visits to Spain and the United States, and the firm became known as one which was prepared to undertake contracts of any description and on the largest scale. A visit to Mexico in 1889 led to the firm's undertaking a number of important contracts for drainage and electric lighting schemes, railways, harbours and waterworks, and to the acquisition of very extensive oil-bearing lands. The development of these oil properties involved Pearson in a period of acute competition with subsidiary companies of the Standard Oil Company. After the war he relinquished his controlling interests in the Mexican oil fields to the Royal Dutch-Shell Group. In 1919 Lord Cowdray made an attempt to exploit the possibilities of oil in Derbyshire, and one of the most recent operations with which his companies were prominently connected was the development of the Kent coalfields.

The enterprises successfully carried through by Pearson during his long career were many and various, and include—to name only a few—such notable examples as

the Blackwall Tunnel under the Thames, for which the honour of a baronetcy was conferred upon him in 1894, the enlargement of Dover Harbour, docks at Hull, Southampton, London, and Malta, the four tunnels under the East River for the Pennsylvania Railway, and the dam across the Blue Nile above Khartoum.

In 1910 Pearson was raised to the peerage, taking the title of Lord Cowdray of Midhurst, and early in 1917 was promoted to a Viscounty. His war services included the construction of the colossal munition factory at Gretna Green, and the Tank assembly factory at Chateauroux. He was also Chairman of the Air Board during the greater part of 1917. In 1925 he received the G.C.V.O. His benefactions to charitable and public objects, with which Lady Cowdray was closely associated, were large and numerous.

Lord Cowdray had been a Fellow of the Society since 1896, and was a Vice-President from 1912 to 1914.

NOTES ON BOOKS

THE STUDY OF WAR. Edited by Major-General Sir George Aston, K.C.B. London: Longmans, Green and Co., Ltd. 10s. 6d. net.

As the Editor points out, the subject of War, as a study affecting the general education of statesmen and civilians, has been singularly neglected in this country; and the effort which has now been made to remedy this state of affairs, by means of lectures in the University of London, delivered by distinguished members of the fighting Services, is one that merits considerable attention.

In the present volume a series of these lectures is reprinted, prefaced by an introductory address by Viscount Grey of Fallodon. The main concern of this address, as also of a preliminary lecture by the Editor, is to commend the civilian study of war on two grounds: that the probability of outbreaks of war will thereby be lessened; and that the necessary authority of civilian Ministers over the conduct of operations will be more usefully (or less harmfully) exercised.

The second proposition is perhaps tinged with a hardly warrantable degree of optimism. Assuming that strategy, in the widest sense, is a subject demanding lifelong professional study, it seems fairly certain that politicians (to whom, after all, war can only present itself as one problem out of very many) will never in this respect attain any other than an amateur status; and when one happens to notice, amongst the publishers' announcements at the back of the volume, a work entitled *The Perils of Amateur Strategy*, by Lieut.-General Sir Gerald Ellison, one hardly knows whether to regard it as a confirmation of this proposition, or as a somewhat grim and ironic comment. It is difficult to doubt that the possession of amateur strategic views by powerful Ministers is a factor which may easily "cut both ways."

The same position, however, is maintained, though with caution, by Sir Charles Oman in the next lecture, which takes the form of a "Defence of Military History." Following this there are separate sections on Sea, Land and Air Warfare, by Vice-Admiral Sir W. H. Richmond, Major-General Sir Edmund Ironside and Air Vice-Marshal H. R. M. Brooke-Popham respectively, and an extremely interesting lecture on Chemical Warfare by Brigadier-General H. Hartley; and the volume concludes with an educational essay by Mr. G. F. Bridge.

The authors take it as axiomatic that war consists in a combined and co-ordinated effort by all branches of His Majesty's forces; and there is here no trace of that mutual impatience, slight but distinct, which is in evidence in many contemporary Service memoirs. Such co-operation is what one would expect under the editorship of Sir George Aston, who is to be congratulated on the success with which his function has been discharged.

GENERAL NOTE.

DECORATIVE AND INDUSTRIAL ART EXHIBITION.—The second annual exhibition of Decorative and Industrial Art will be opened in the Central Hall, Westminster, on May 18th, and will continue daily from 10 a.m. to 8 p.m. until May 28th. The first exhibition, held last year, reached a high standard, and it is anticipated that this year's Exhibition, which is under very distinguished patronage, will achieve a still greater success. The exhibits will cover a wide range and will include the following:—Hand-painted lampshades, hand-made leather, wood and metal work, glass, pottery and porcelain, sculpture, etchings and wood-cuts, book-binding and printing; colour prints and posters, silverware, Indian arts and crafts, weaving, lace and embroidery, drawings and photographic studies.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, MAY 16. Aeronautical Society, at the ROYAL SOCIETY OF ARTS, Adelphi, W.C. 6.30 p.m.
Architects, Royal Institute of British, 9, Conduit Street, W. 8 p.m. Modern Hospital Planning: (1) Mr. H. Percy Adams, "English Hospitals"; (2) Mr. Lionel G. Pearson, "American Hospitals." Geographical Society, at 135, New Bond Street, W. 8.30 p.m.
University of London, at King's College, Strand, W.C. 5.30 p.m. Don Américo Castro, "Cervantes Artista del Renacimiento Español" (in Spanish). (Lecture I.)
5.30 p.m. The Rev. Claude Jenkins, "Some Modern English Historians." (Lecture III.) "Creighton."
5.30 p.m. Mr. Henry Wickham Steed, "Hungary and Czechoslovakia."
At the London School of Economics, Houghton Street, Aldwych, W.C. 5 p.m. Mr. G. V. Portus, "Political Theory and Economic Experimentation in Australia." (Lecture I.)
At the London School of Medicine for Women, 7, Hunter Street, W.C. 5.30 p.m. Prof. H. Beckwith Whitehouse, "The Menstrual Function, its Physiology and Pathology." (Lecture I.)
At the Middlesex Hospital Medical School, Cleveland Street, W. 5 p.m. Prof. Dr. John Fraser, "Some Surgical Problems." (Lecture I.)
At University College, Gower Street, W.C. 5 p.m. Prof. Dr. G. Dawes Hicks, "Ruskin's Theory of Art." (Lecture III.)
5.30 p.m. Major George Haven Putnam, "England and America, their relations in the Past and their Obligations to each other To-day."
Victoria Institute, at the Central Hall, Westminster, S.W. 4.30 p.m. Dr. R. Sallens, "Rationalism and its Influence on the French Churches."

TUESDAY, MAY 17. Statistical Society, at the ROYAL SOCIETY OF ARTS, Adelphi W.C. 5.15 p.m.
University of London, at King's College, Strand, W.C.2. 5 p.m. Prof. Dr. R. J. S. McDowall, "Autonomic Nervous System." (Lecture III.)
At the Middlesex Hospital Medical School, Cleveland Street, W. 5 p.m. Prof. Dr. John Fraser, "Some Surgical Problems." (Lecture II.)
At the Royal School of Mines, South Kensington, S.W. 5.30 p.m. Dr. F. F. Blackman, "Problems of the Respiration of Plants." (Lecture II.)
At University College, Gower Street, W.C. 5.30 p.m. Mr. W. H. McLean, "National, Regional and Town Development Planning." (Lecture II.)
5.30 p.m. Air Vice-Marshal Sir Philip Game, "Air Power and Imperial Defence."

WEDNESDAY, MAY 18. British Academy, at Burlington House, W. 5 p.m. Prof. G. C. Moore Smith, "Thomas Randolph." (Warton Lecture.)
Chemical Society, at the Royal Institute, Albemarle Street, W. 5.30 p.m. Prof. Dr. Richard Willstätter, "Problems and Methods in Enzyme Research." (Faraday Lecture.)
Electrical Engineers, Institution of, Savoy Place, W.C. 6 p.m. Mr. P. K. Turner, "A Wireless Works Laboratory."

Meteorological Society, 49, Cromwell Road, S.W. 5 p.m.
(1) Dr. Harold Jeffreys, "Cyclones and the General Circulation." (2) Mr. George M. Meyer, "Early Water-mills in relation to Changes in the Rainfall of East Kent." (3) Mr. S. Morris Bower, "Report on Winter Thunderstorms in the British Isles from January 1st to March 31st, 1926."
University of London, at King's College, Strand, W.C. 5.30 p.m. M. le Professeur F. Brunot, "Pourquoi j'ai cru nécessaire de Proposer une Classification Nouvelle des Faits du Langage?" (in French).
5.30 p.m. The Rev. F. R. Barry and Rev. A. S. Duncom-Jones, "The New Prayer Book." (Lecture II.)
At the London School of Economics, Houghton Street, Aldwych, W.C. 5 p.m. Mr. C. S. Orwin, "The Economics of Agriculture." (Lecture I.)
At the London School of Economics, Houghton Street, Aldwych, W.C. 5 p.m. Dr. Hubert Hall, "Housekeeping in Six Centuries (1200-1800)." (Lecture IV.)
At the Middlesex Hospital Medical School, Cleveland Street, W. 5 p.m. Prof. Dr. John Fraser, "Some Surgical Problems." (Lecture III.)
At the School of Oriental Studies, Finsbury Circus, E.C.2. 12 noon. Mr. T. A. H. Way, "Indian Administrative Law." (Lecture IV.)
5 p.m. Count Leon Ostrog, "The Reform of Turkish Law." (Lecture II.)

THURSDAY, MAY 19. Birth Control, Society for Constructive, at Essex Hall, Strand, W.C. 8 p.m. Mrs. H. Earl, Mrs. T. Edmunds and Mr. A. W. Goodman, "What Converted me to Birth Control and what I should like to see done for the Movement."
Chemical Society, Burlington House W. 8 p.m. Mr. H. M. Dawson, "New Developments in the Study of Acid Catalysis. The Catalytic Catenary."
Mining and Metallurgy, Institution of, at Burlington House, W. 5.30 p.m.
University of London, at King's College, Strand, W.C. 5.30 p.m. Don Américo Castro, "Cervantes Artista del Renacimiento Español" (in Spanish). (Lecture II.)

FRIDAY, MAY 20. Royal Institution, 21, Albemarle Street, W. 9 p.m. Prof. W. L. Bragg, F.R.S. "The Structure of the Silicates."
Sanitary Institute, at Bath. 7.30 p.m. Dr. H. T. Herring, "Cremation."
University of London, at Guy's Hospital Medical School, St. Thomas's Street, S.E. 5.30 p.m. Prof. Dr. E. H. Kettle, "Inflammation and Infection." (Lecture I.)
At King's College, Strand, W.C. 5.30 p.m. Monsieur Denis Saurat, "Marcel Proust" (in French). (Lecture I.)
5.30 p.m. Mr. J. A. K. Thomson, "The Logos in Herodotus."
At University College, Gower Street, W.C. 5.30 p.m. Prof. Dr. John Burnet, "Platonic Problems." (Lecture II.)

SATURDAY, MAY 21. Arts, League of, at the Victoria and Albert Museum, South Kensington, S.W. 3 p.m. Penelope Wheeler, Dramatic Recital of the Hippolytus of Euripides.
Sanitary Institute, at Bath. Mr. F. P. Sissons "Sewage Disposal."



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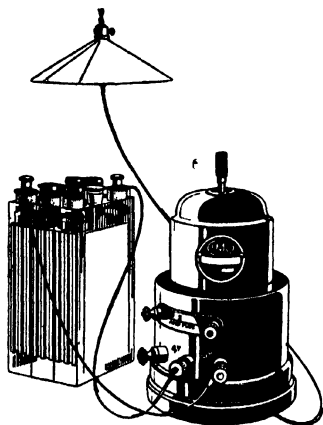
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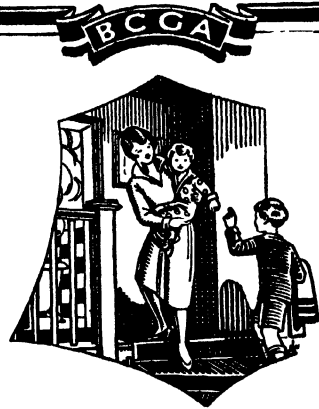
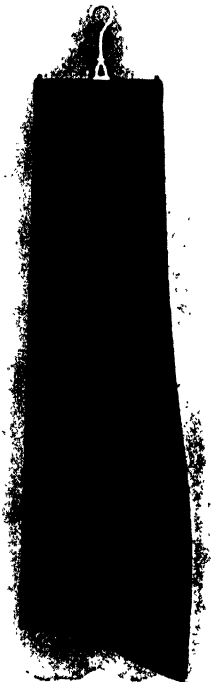
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13 JUN. 1927

JOURNAL OF THE ROYAL SOCIETY OF ARTS

No. 3887

VOL. LXXV.

FRIDAY, MAY 26th, 1927.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2.)

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The Council are extremely anxious to secure a generous response to the Prime Minister's Appeal. It cannot be said that so far this result has been achieved, and they therefore earnestly beg all those who have any feeling for the charm of the countryside to subscribe to the Fund and to do what they can to interest their friends in the movement. Every day beautiful old cottages are being threatened with demolition, and unless help is forthcoming at once many will be lost for ever.

Mr. Baldwin's Appeal on behalf of the Fund, together with a Note by Mr. Thomas Hardy, has been issued as an illustrated pamphlet, and the Secretary will be glad to send copies to all who apply for them.

THE SOCIETY'S HOUSE.

DECORATION OF THE REAR WALL.

When the Society's House was built by the Brothers Adam, its back wall faced the backs of other buildings and was not visible by the public. Owing, however, to the recent widening of the Strand, this wall was suddenly brought into prominence, and its unfinished ugliness was emphasised by its proximity to the new buildings on either side of it. The matter was considered by the Council, who at once realised the advisability of taking steps to improve the appearance of the back; but in view of the fact that there is still a deficit on the Building Fund, they were unwilling to expend further money on the house.

In these circumstances Sir George Sutton generously intervened. Fifty years ago he obtained a first-class certificate in book-keeping at the Society's examinations; he is now a member of the Council and a Vice-President of the Society, and he expressed his desire to commemorate the jubilee of his first connexion with the Society by bearing the whole cost of the decoration of the wall. The Council gratefully accepted his offer and plans were prepared by Sir Aston Webb and Son.

The work has now been completed. The first photograph shows the wall as it used to be; the second shows the blank wall above the window as it now appears. This space has been decorated with an Adam design, the motif and details of which have all been taken faithfully from the front of the house

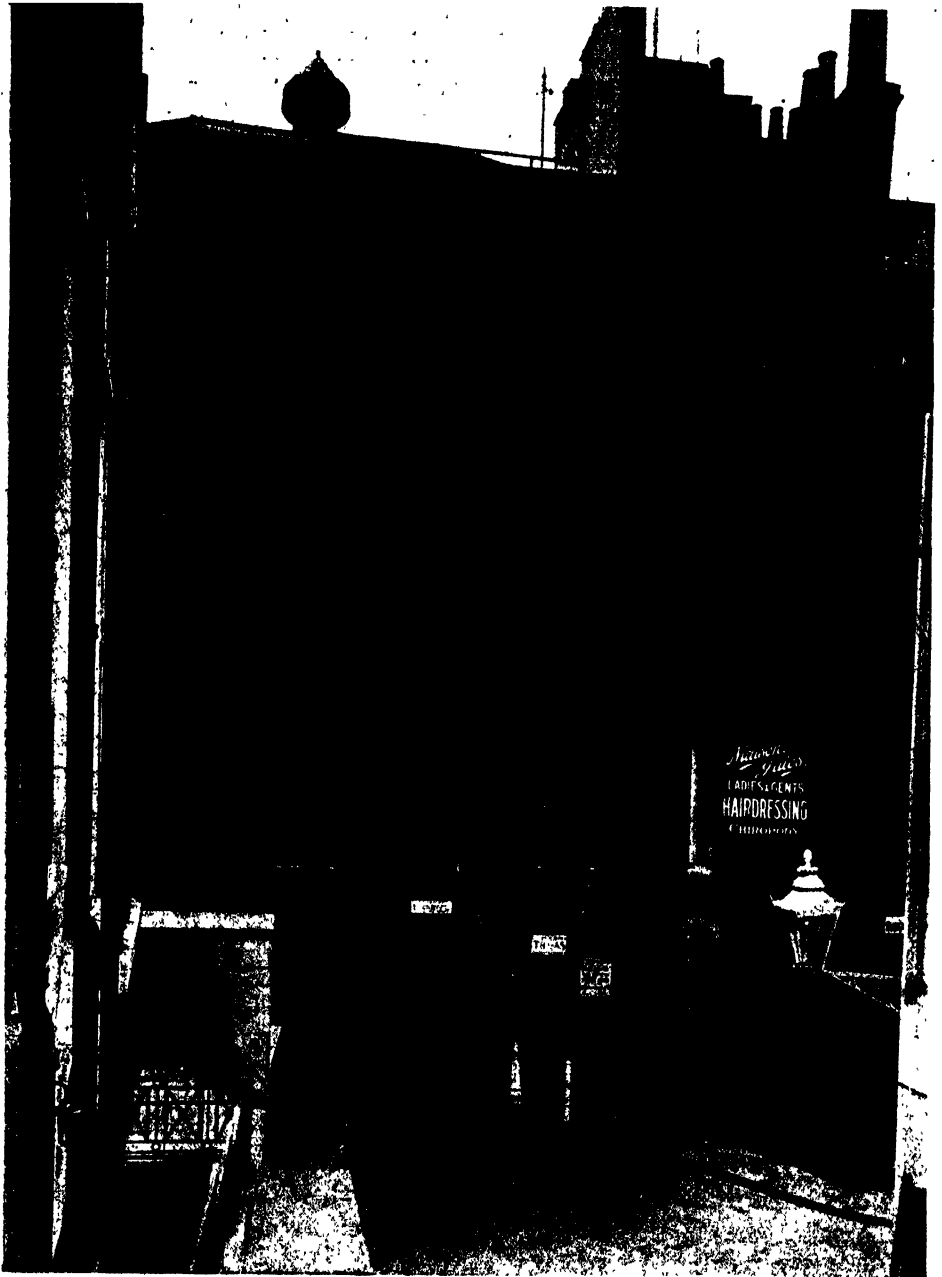


FIG. 1.—Back of Society's House, before decoration.

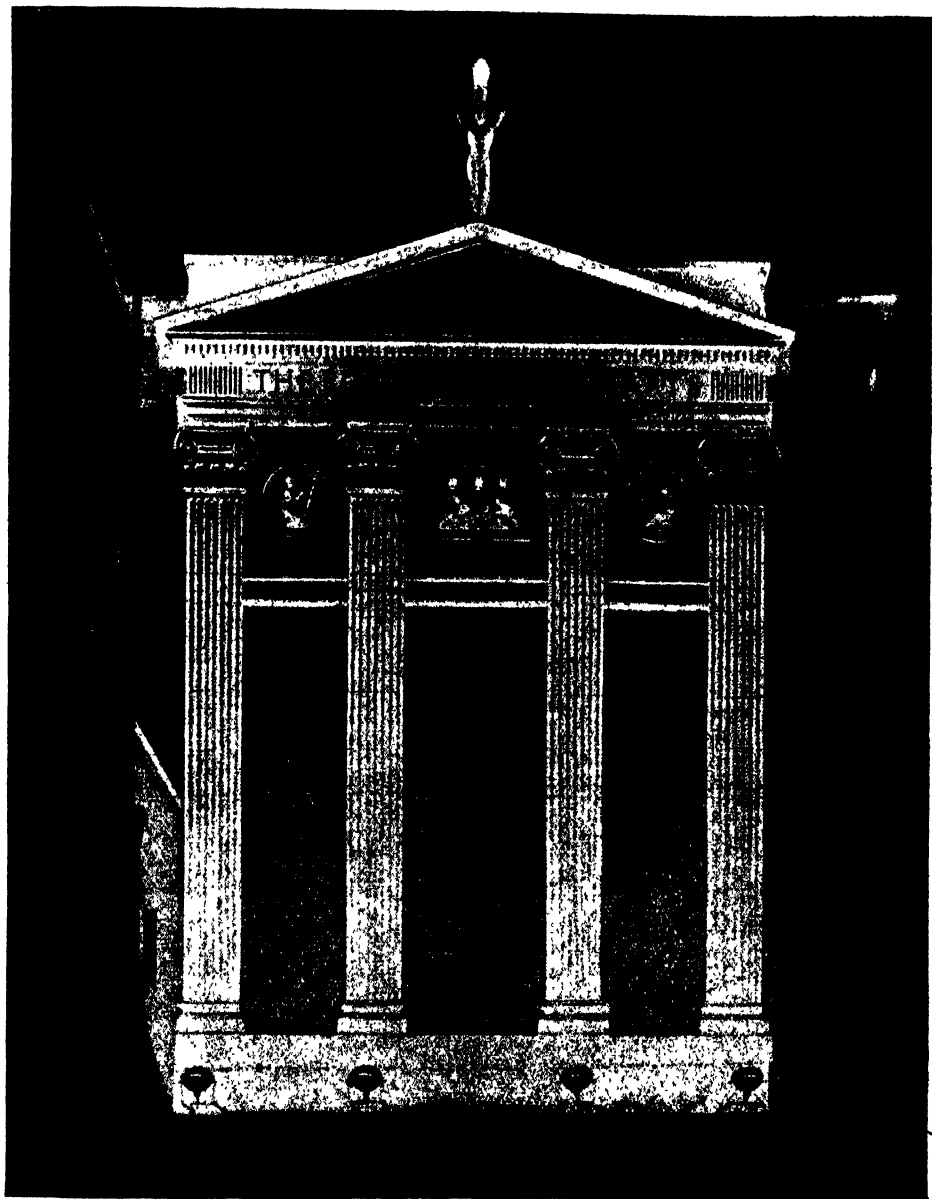


FIG. 2.—Decoration of the blank wall above the window, as it now appears. The photograph shows the wall as illuminated by flood light.

in John Street. The design is carried out in cement fixed on to the existing brickwork, and consists of four pilasters carrying a pediment surmounted by a figure designed and executed in concrete by Mr. Walter Gilbert.

The underlying idea is to show that when the rest of the Adelphi is sold the Royal Society of Arts intends to retain an historic building, which marks an epoch in British architecture.

The reliefs in the spaces between the pilasters were modelled and cast by Mr. E. J. Bradford, whose firm also carried out the rest of the cement work. Messrs. Dove Bros. were the general contractors.

DINNER TO SIR GEORGE SUTTON.

In recognition of Sir George Sutton's generosity, Members of the Council entertained him to dinner at the Athenæum on April 28th. Those present were:—Sir Thomas Holland, K.C.S.I., K.C.I.E., F.R.S. (Chairman of the Council); Lord Askwith, K.C.B., K.C., D.C.L.; Sir Charles H. Armstrong; Mr. Llewelyn B. Atkinson; Sir Charles Bayley, G.C.I.E., K.C.S.I.; Captain Sir Arthur Clarke, K.B.E.; Mr. P. M. Evans, LL.D.; Sir Robert Hadfield, Bt., D.Sc., F.R.S.; Rear-Admiral J. de C. Hamilton, M.V.O.; Major Sir Humphrey Leggett, R.E., D.S.O.; Sir Philip Magnus, Bt.; Sir Reginald Mant, K.C.I.E., C.S.I.; Mr. G. K. Menzies; Sir Richard Redmayne, K.C.B.; Mr. A. A.-Campbell Swinton, F.R.S.; Mr. Carmichael Thomas; Dr. J. A. Voelcker; Mr. Maurice Webb, D.S.O., M.C., F.R.I.B.A.; Lieut.-Colonel Sir Arnold T. Wilson, K.C.I.E., C.S.I., C.M.G., D.S.O.; and Sir Alfred Yarrow, Bt., F.R.S.

TWENTIETH ORDINARY MEETING.

WEDNESDAY, MAY 11th, 1927. BRIGADIER-GENERAL SIR BRODIE H. HENDERSON, K.C.M.G., C.B., M.Inst.C.E., in the Chair.

The following candidates were proposed for election as Fellows of the Society:—

Amies, Arthur Barton Pilgrim, L.D.S., Edinburgh.

Armstrong, John James Victor, Liverpool.

Campbell, Roy, London.

Fiedler, Svend G., London.

Kuntz, William Jacob, York, Pennsylvania, U.S.A.

Lockwood, Kemp, A.M.I.Mech.E., Stoneycroft, Liverpool.

Neilson, William Hardcastle, O.B.E., M.Inst.C.E., M.I.Mech.E., Bombay, India.

Webster, William Reuben, Bridgeport, Conn., U.S.A.

Winecoff, Miss Anna Thompson, B.A., Laramie, Wyoming, U.S.A.

The following candidates were duly elected Fellows of the Society:—

Clark, Norman G., Melbourne, Australia.

Connell, W. H., London

Cullinan, Joseph S., Houston, Texas, U.S.A.

Dass, Janaki Nath, B.A., Ingabu, Lower Burma.

Enright, Robert John Patrick, Pallavaram, South India.

Foss, Feodore F., Wheeling, Virginia, U.S.A.

Harris, Major-General George Francis Angelo, C.S.I., M.D., F.R.C.P., London.

Hart, Charles, Chester, Pa., U.S.A.

Horder, P. Morley, F.S.A., London.

Nawn, High, Boston, Mass., U.S.A.

Pratt, Arthur, Johannesburg, South Africa.

Takeda, Admiral Hideo, I.J.N. (ret'd.), Tokyo, Japan.

Toll, Pelham, E.S., Hove, Sussex.

Whittier, Charles E., Chicago, Illinois, U.S.A.

Wright, James Alpheus, Montreal, Canada.

The second of a course of two lectures on "English Railways," given under the Dr. Mann Trust was delivered by PROFESSOR WILLIAM E. DALBY, M.A., F.R.S., M.Inst.C.E., M.I.Mech.E., Dean of the City and Guilds (Engineering) College, Imperial College of Science and Technology.

The lecture will be published in the *Journal* dated July 8th.

COUNCIL.

A meeting of the Council was held on Monday, May 9th. Present :—Sir Thomas Holland, K.C.S.I., K.C.I.E., D.Sc., F.R.S., in the Chair ; Sir Charles H. Armstrong ; Lord Askwith, K.C.B., K.C., D.C.L. ; Llewelyn B. Atkinson, M.I.E.E. ; Sir Frank Baines, C.V.O., C.B.E. ; Sir Charles Stuart Bayley, G.C.I.E., K.C.S.I. ; Captain Sir Arthur Clarke, K.B.E. ; Mr. Peter MacIntyre Evans, M.A., LL.D. ; Sir Edward A. Gait, K.C.S.I., C.I.E. ; Rear-Admiral James de Courcy Hamilton, M.V.O. ; Col. Sir Arthur Holbrook, K.B.E., M.P. ; Sir Herbert Jackson, K.B.E., F.R.S. ; Sir Philip Magnus, Bt. ; Sir Reginald A. Mant, K.C.I.E., C.S.I. ; Sir George Sutton, Bt. ; Mr. Alan A. Campbell Swinton, F.R.S. ; Mr. Carmichael Thomas ; Sir A. T. Wilson, K.C.I.E., C.S.I., C.M.G., D.S.O. ; and Sir Alfred Yarrow, Bt., F.R.S., M.Inst.C.E., with Mr. G. K. Menizes, M.A. (Secretary) and Mr. W. Perry, B.A. (Assistant Secretary).

The question of the award of the Albert Medal for 1927 was further considered, and names were selected for submission to H.R.H. the President.

Consideration of the balloting list for the new Council was begun, and vacancies were declared.

The scheme for the administration of the Fund for the Preservation of Ancient Cottages, as amended by the Hon. Solicitors, was approved.

The number of entries for the May Examinations was reported—38,512.

A committee was appointed to consider the award of medals for papers read before the Society during the current session.

A quantity of financial and formal business was transacted.

REPRINT OF HOWARD LECTURES.

The Howard Lectures on "Recent Experiments on the Properties of Steam at High Pressures," by Professor H. L. Callendar, C.B.E., LL.D., F.R.S., have been reprinted from the *Journal* in pamphlet form. The reprint (price 2s.) can be obtained from the Secretary, Royal Society of Arts, John Street, Adelphi, W.C.2.

A full list of lectures which have been published separately and are still on sale can also be obtained on application.

PROCEEDINGS OF THE SOCIETY.

SIXTEENTH ORDINARY MEETING.

WEDNESDAY, MARCH 23RD, 1927,

THE RT. HON. LORD CLINTON in the Chair.

THE CHAIRMAN said he regretted—as he was sure the audience would—the absence of Lord Bledisloe, who was to have taken the Chair that evening. He knew how much Lord Bledisloe, who, unfortunately, was prevented from being present owing to illness, regretted being unable to attend, both on account of the interesting subject which was to be dealt with and also on account of the personality of the lecturer.

The following paper was then read:—

THE TRANSITION OF AGRICULTURE.

By C. S. ORWIN, M.A.

Director, Agricultural Economics Research Institute, University of Oxford.

The subject of this address was not selected by me, but at the same time it seems not inappropriate to the state of affairs which we find within the agricultural industry of this country to-day. Economic conditions are such that over wide areas something has got to happen if the industry is to carry on, assuming, of course, that these conditions are likely to have some permanence; and it follows that a transition from the present condition is inevitable.

Transition periods in agriculture are to be noted all through its history, and the changes introduced in farming practice at these times have been due, all of them, to the need for industrialising the industry. The earliest is represented by the enclosure of the open fields. Open field farming had worked well enough while the business was still carried on almost exclusively as a means of satisfying the wants of the cultivator himself and the small community of which his class formed the principal part; but so soon as the

opportunities for the exchange of commodities began to widen, the limitations of the system became apparent, and it had to go. Enclosure was a continuous process from the end of the Middle Ages and went on even up to the present day, for so recently as 1914 an Order was made by the Board of Agriculture for the enclosure of a Gloucestershire parish. But in the history of this transition two periods of particular activity are clearly marked. The first of these occurred in Tudor times, and whilst the causes which led to it were various and time does not admit of their consideration in detail, the principal one was undoubtedly the growth of an export trade in wool. Sheep-farming on an extensive scale was impossible under the system of common field farming, and so the practice began of consolidating the holdings and laying down the plough-lands, hitherto devoted to corn-growing, to pasture. The system of sheep-ranching which followed made undoubtedly for the profit of the few, but it led to unemployment, in the absence of alternative work in urban industry, and to the scarcity of bread, in the absence of alternative supplies of corn. This period of transition in farm organisation may be said to have begun in the reign of Henry VII and to have continued into the early years of Elizabeth's reign, and much of the social legislation of the time was directed towards attempts to check it. Evidence of the importance of the trade in wool and of the profit to the individuals concerned at this time survives to-day in the "Woolpack" inn sign, and in the magnificent tombs of the woolstaplers to be seen in many of the Cotswold churches.

The second period of activity in enclosure is that which is marked by the reign of George III. It was during this time, the latter half of the eighteenth century and the early decades of the nineteenth, that the countryside came to assume its present appearance. The causes in this case were entirely different from those which brought about the Tudor enclosures. The Hanoverian farmers found themselves called upon to meet the food requirements of an ever-growing industrial population, and at the same time they had at command new crops and new methods of farming, introduced from the Continent, which could not be grown or applied under the restrictions of open field, or strip farming.

The enclosures in the early 16th century did not represent improved farming, for the conversion of arable land into sheep-walk was a retrograde rather than a progressive movement. In the eighteenth and early nineteenth centuries it marked the introduction of better farming practice. As Lord Ernle has pointed out, enclosure in the sixteenth century was opposed and arrested by legislation; in the eighteenth century it received Parliamentary encouragement and support. In Tudor times dearth of bread was the most effective cry against the movement; under George III it was the unanswerable plea for its extension.

Thus, by the time of the accession of Queen Victoria the face of the country had undergone an almost complete change, and the great fields, farmed mostly

in half-acre strips for hundreds of years, as can still be seen surviving in one or two places in England to-day, had given place to the compact fields and farms as they now appear. In some places, farmers and their men have continued to live for the most part in the villages and to walk out to their fields. In most districts, new farmhouses and cottages came, in course of time, to be erected over the parish on the newly consolidated holdings, and this break-up of the village community has done much to bring about the distaste for country life which is evident in agricultural workers, more particularly in these days, when the house-wife is more dependent upon the village shop and when attendance by her children at the village school is compulsory.

By this time, the beginning of Victoria's reign, the face of the country and the organisation of farming had become fairly settled more or less in its present form. Fortune varied, as it always will, and new practices were introduced with the progress of science and invention; but nothing occurred to bring about any great transition until the opening of the eighth decade of last century. The transition which then set in was very different both in its causes and its nature from the preceding one. Whereas the changes in the eighteenth century were directed towards higher farming, and were brought about by the deliberate action of the agricultural leaders of the time, the great transition of the eighties and nineties of last century was the result of declining fortune, and was forced upon a reluctant agricultural community. The causes are mostly notorious, and there were many which contributed to the final result. The development of railways in the New World, bringing vast areas of land within reach of the ports, the invention of the self-binder and other labour-saving machinery, making prairie cultivation on an extensive scale possible even in sparsely-populated districts, the increase in the production of gold, all these and other things combined to bring about a steady decline in the price of the products of arable land, wheat, for example, falling from an average figure of 56s. 9d. per quarter in the year 1877 until the year 1894, when it reached the lowest figure of the century, namely, an average of 22s. 10d. per quarter for the whole country, though at times in many markets good grain was sold even down to 18s. per quarter. Moreover, this period of decline had been preceded by a cycle of years of bad weather and disease, and the cumulative effect of these things was to drive out of arable cultivation no fewer than 4,000,000 acres of land, and to reduce the population working on the land by no fewer than a quarter of a million people.

All this plough land reverted in the first instance to grass, much of it by the process known as "tumbling down," which means, of course, that the land was left derelict until Nature established a herbage of her own upon it. Much of it, however, was seeded down, thus speeding up and carrying out more effectively the transition from arable to grass. No small part of it was lost to any kind of husbandry, and in the process of time became first of all covered with bushes,

and finally reverted to the state of natural woodland, from which our early ancestors must at one time have reclaimed it. The figures given above indicate the magnitude of this change in the farming system of the country, but a better impression of what it has meant in the aspect and life of the countryside may be got by an inspection of any of the predominantly grass districts of England. Stand on a hill in High Leicestershire and look across the great grazings of that county; motor through the clay lands of Warwickshire; stand, again, above Dauntsey, in Wiltshire, and look across its fertile valley, or on the edge of Salisbury Plain and look across the vale of Pewsey. At each of these spots, so far as the eye can reach, there is nothing but grass-land to be seen, and every field shows the ridge and furrow formation indicative of a former period of arable cultivation. On the coldest and wettest of the clays, as, for example, in the neighbourhood of Bicester, or along the Fosse Way in Nottinghamshire, it is possible to walk through woodlands and thickets which show the same indications of tillage, though probably most of these are cases where reversion from arable farming took place at an earlier date, for a similar transition on a much smaller scale had occurred after the Napoleonic Wars, during which the prices to which wheat soared had brought under the plough considerable areas of land which lay normally outside the margin of cultivation.

This late Victorian transition occupied about five and twenty years. The heavy loss to landlords and farmers that it occasioned is common knowledge; but by the year 1906 the necessary adjustments had been made and by means of stock-raising, stock-feeding, and particularly by the development of the dairy industry farmers had re-established themselves upon a new basis, and although the agricultural industry, as it emerged, was a smaller one and probably less productive, from that date onwards to 1914 conditions were fairly stable, with a tendency to improve. Except in numbers, the agricultural labourer alone had suffered no reverse during the transition period. The expansion of urban industry and the development of our Colonial Empire provided him with alternatives to farm work at home and prevented any decline in rates of wages, although it must be admitted that they remained at a comparatively low level.

The next transition, brought about by the Great War, calls only for the briefest reference. Under stress of circumstances land laid or tumbled down to grass in the 'eighties and 'nineties was once more brought under the plough to the extent of 1,400,000 acres; but seven years following the conclusion of hostilities sufficed to put it back again, and, as regards its area of plough land, England to-day is back once more in the position represented by 1914, with a tendency for still more land to revert to grass. A more important circumstance attending these two most recent periods of transition, and one which bears more directly upon conditions of present-day agriculture, is the intervention by the State to regulate the remuneration of farm labour. The establishment in 1917

of a central Agricultural Wages Board and, at a later date, of County Agricultural Wages Committees, with powers to fix remuneration of different classes of farm labour, has introduced a new element into the situation which, in my opinion, will be the dominating factor in the future development of rural industry.

The foregoing summarises very briefly some of the more important transitional periods in the history of British Agriculture. The facts concerning most of them are common knowledge, but no apology is needed for this summary, as some understanding of them is essential to a consideration of the present position of the industry and to a forecast of its probable lines of development. The position of agriculture to-day gives much concern to those who are familiar with it. The problem created by the break-up of so many of the great estates (during the last ten years more than 25 per cent. of the agricultural land of England has passed into the hands of new owners) is a special one which cannot be considered here; but in other respects farming over large areas is passing through a very trying time. In the ten years before the War, as already noted, farmers had contrived more or less to adjust themselves to the prevailing conditions. During the period of the War, although their business was conducted under great difficulty, their profits were substantial. But in the nine years of peace the efforts of the Government to re-establish the value of the £ sterling, combined with the lack of purchasing power of the principal food-importing countries, which has made England a dumping ground of the surplus products of the primary producers of the world, have produced a situation which, if it continues, seems bound to mark the beginning of another transitional period in agricultural organisation.

Generalisations covering the whole country cannot be made. There are still certain districts in which general agriculture is being carried on profitably under prevailing conditions, and it is probably true that there are certain branches of this very varied industry which are yielding a return on the capital invested in them, in whatever locality they are practised. But even in places favourable to general agriculture, and in certain apparently successful forms of specialist farming, it is open to doubt whether the present conditions, particularly those relating to the remuneration of labour, can be expected to continue, whilst over the greater part of the country—on the “pound an acre land”—some early change in farm organisation seems almost to be inevitable.

Agriculture is the second largest industry in the country, giving employment to some 550,000 workers for wages. Even in the more favoured districts it is doubtful whether the standard of comfort which it affords to these workers approximates to that of the lowest paid industrial labour, whilst over the greater part of the country the standard is very definitely inferior. Already the effects of this position are noticeable and they will become more and more serious. Although farm work is entirely free from the monotony which characterises much industrial employment, and although it calls for a large

measure of skill in those engaged in it, the low economic status which it affords is steadily driving more and more of the best stamp of rural worker to seek other outlets, if not for himself, at all events for his children. An organiser of an agricultural labourers' union may be quoted for the statement that the rural worker of to-day has come to regard farm-service for his sons (and domestic service for his daughters) as something derogatory and bearing the stamp of failure. An enquiry undertaken by schoolmasters in selected rural parishes at the instance of the Secretary for Education in a South Midlands county revealed an almost unanimous desire on the part of the parents of the boys to find employment for them in industries other than agriculture ; and there is no doubt that there is a growing stigma attaching to the lad who remains in farm service, just as it is the experience of domestic servants attending dance clubs and similar social organisations that the girls from the shops and from the factories are unwilling to mix with them upon equal terms.

We are not concerned with the problem of domestic service, but as regards the farm-labourer, my view is that the difficulty is almost entirely one of his economic status. The lure of the town is doubtless real, and to certain types of mind nothing will ever compensate for the interest and excitement of urban life. " I can always get all the unskilled labour I want," remarked the manager of one of the great Lincoln foundry companies, " by paying half-a-crown a week more than the farmer pays." This was before the War, and the difference will be greater now ; but it is common knowledge that town life has an irresistible attraction for some. Nevertheless, it is true, probably, that if it were possible to raise the economic position of the farm labourer more nearly to that of his opposite number engaged in urban industry, the problem of the retention of the best class of rural worker on the land would be solved, and the growing stigma attaching to this form of service would be removed once and for all. Apart from the opinions quoted above there is statistical evidence of the existence of this desire to leave the land. A study of the age classes of land workers shows that the proportion represented by boys entering farming after the school age is high ; and similarly that the proportion of men over 40 years of age is high. It is on arrival at manhood and during the years following that the big drift into the towns occurs. At the age of 21 the farm worker has arrived normally at the summit of his profession. It has nothing more to offer him in the way of advancement. Moreover, the spirit of the times demands more and more insistently a higher standard of comfort for the rural dweller. It is true that in England the standard is higher than in any European country. Notwithstanding all that has been said about the life of the Continental peasant, his success is based upon a standard of living lower than that of the worst-paid English farm-labourer, and his apparent content with his lot is due to the absence of opportunity for contrasting it with that of those in better circumstances.

Where all are poor, all may be said to be rich, and in no country in Europe is there the striking contrast which exists in England between the economic condition of the average farm-labourer and that of his kinsmen and friends engaged in urban industry. Thus the tendency is all the time to raise the wage of the farm-worker. Public opinion demands it, the leaders of the Trades Union Movement are working for it—for this mass of relatively low-paid labour exerts a depressing influence upon Trades Union rates in general—and the great question is: Can agriculture as at present organised stand for it?

Under present conditions of farm organisation the answer can only be "no." The opinion expressed by an experienced and well-known farmer at a recent meeting of the Farmers' Club epitomises the views of innumerable of his fellows up and down the country:—"I think I am voicing the opinion of every farmer in this room when I say that we are willing to pay as high wages as any other class in the country if we can only afford to do so; but as everyone present knows, owing to the low price of corn, meat and other farm products we cannot pay any more. The consequence is that, round about my neighbourhood, the younger men, who have come to you as boys, go off as soon as they can into the factory. We are dependent on the elder men: What will come to us when they are gone I do not know."

The assertion that agriculture cannot pay higher wages is so generally made that it is desirable to find some way of testing it. Accordingly my colleague, Mr. Whatham, has made some recalculations of the financial results of farming, assuming that labour were remunerated at rates prevailing for unskilled workers in urban industry (obtained by the courtesy of the Ministry of Labour). For the first test a group of twenty-five farms in the Eastern Counties was taken, detailed accounts relating to which for the year 1925 have been published by Mr. J. A. Venn. Of this group, five holdings showed an original loss, and as to the remaining twenty a recalculation of the labour costs on the basis of urban wage-rates resulted in a loss on ten of them; but the ten still showing a credit balance on the year's working included four on which this represented less than ten per cent. on the capital invested.

For the second test a group of twenty-four farms in the South Midlands was taken, accounts for which during the same period have been prepared by my colleague, Mr. S. J. Upfold. In this case, no fewer than fourteen holdings showed an original loss, and on recalculation of the labour bill on the basis of urban wage-rates, as before, three others failed to stand the test, whilst out of the seven remaining, no fewer than five showed a balance representing less than ten per cent. on the capital invested.

Taking the forty-nine farms in these two groups together, it appears that nineteen show an original loss; thirteen others show a loss when the remuneration of labour is raised to industrial rates, whilst of the seventeen remaining no fewer than nine show a balance insufficient to pay ten per cent. on

the capital invested in them—a rate which must err on the low side when it is remembered that farming is a risky business and that the balance has to provide not only a return on capital, but also the farmers' remuneration as manager. Thus more than eighty per cent. of the farms comprised in this sample fail to stand the test of competitive wages. It must be noted, too, that the farms in the Eastern Counties group include some on the best land in England, and that considering both groups it is probable that they constitute a sample above the general average of the country as a whole.

One interesting fact which emerged from Mr. Whatham's study of these figures is that in all cases in both groups where a loss is shown, either in the original or in the recalculated results, the actual labour bill bears a ratio of more than fifty per cent. to the value of the net output of the farm. Again, on all these unprofitable farms, regardless of location, size, or system, the amount of the wages bill exceeds thirty-five per cent. of the total outgoings.

Admittedly the foregoing tests are very rough and inadequate, but they may be taken as affording some confirmation of the general contention that farming cannot afford higher wages, and we are faced with the fact that more than half-a-million men, with their wives and families, are engaged in an industry which cannot maintain them in a standard of life comparable to that of their fellow countrymen.

What is to be the transition at this juncture? Direct State-aid for agriculture, either in the form of protection or subsidies, would settle the problem out of hand. For some time past fresh pork has enjoyed absolute protection in the endeavour to stamp out foot-and-mouth disease, and pigs are the only live-stock which did not sustain a heavy fall in market values during 1926. Again, the price procurable for sugar-beet makes it admittedly the most profitable arable crop (on many farms the only one) and this is the result of the subsidy to home-grown sugar. But, in spite of these examples of what may be accomplished by artificial aids, any general system of protection for agriculture is impossible on all grounds. A nation dependent in the main on its foreign trade cannot afford the expensive home production of farming products, for its manufacturers for export are in direct competition with the farmer; the bottom has long since been knocked out of the argument that the maintenance of national health is dependent upon a flourishing rural community; it is clear from their acquiescence in the rapid decline of arable cultivation that those responsible for national defence attach no importance to the maintenance of home production from the land.

In these circumstances, and bearing in mind that the limited areas of more fertile arable land and rich grazings, together with any slight extension of the more intensive forms of agriculture, such as fruit-growing and market-gardening, are definitely excluded from our consideration of the subject under discussion, two possible directions in which the bulk of the agriculture of the country may proceed are indicated. The first of these is the steady multiplica-

tion of small holdings. The small holder escapes the great disability which faces the larger farmer to-day, namely, the necessity of paying wages in competition with the large scale industrial producer. The family farmer, to give the smallholder a better title, has no wages bill. He recognises no overtime, nor does the necessity for Sunday work affect his labour costs. He can and will work all the hours that there are, and his wife and children will contribute their labour to his enterprise in return for a mere subsistence. These are the conditions which make for the success of small holdings in all the peasant countries of Europe, and granting them, there is no reason why British agriculture should not be regenerated on similar lines. It would mean an increased population on the land, and a larger product from it ; but it would mean at the same time a general lowering of the standard of living of those engaged in the farming industry. The progress of social life in England for a long time past has been in the direction of increasing the efficiency of labour by every sort of ingenuity, so as to reduce the hours of work and to increase its monetary reward, and from this standpoint an extended small-holdings policy, entailing long hours of labour for a small return, is definitely anti-social. The older political parties of the State have warmly espoused the policy, partly from a well-meaning desire to provide a ladder for the labourer, partly from a false reading of the apparent contentment of the Continental peasant, but mainly in the hope of increasing what is one of the most stable elements in the political life of the State. The Labour Party, on the other hand, will have nothing to say to small holdings. It recognises that contrasted with standards of life in urban enterprise the small holding community can be regarded only as engaged in a sweated industry, and that the chances of any wholesale development along these lines are not only undesirable, but impossible, in a community where so much alternative work remunerated at a higher rate is on offer. A Belgian Government official, after paying tribute to the great political value of the peasant farmers of Flanders, and belauding their industry, told me that he regarded the attempt to create a similar class in England as hopeless. " There is no country in the world," he said, " where the opportunities of better paid work in other forms of enterprise are so great ; on the other hand, if a man wishes still to follow agriculture there is no part of the world in which he will not find better opportunities than on an English small holding, whilst at the same time living under his own flag and amongst people who speak his own language." It cannot be denied that many men have made good on small holdings, but their numbers are relatively few, and they belong to that small class of rather angular individuals who cannot get the life they want, except as controllers of their own destinies. The transition of agriculture is not going to proceed very far in this direction.

The second direction in which change may proceed is one diametrically opposed to the foregoing. The possibility of it has been indicated already

by Sir Daniel Hall, in his book "Agriculture after the War," and certain striking examples of it may already be found. It consists in the development of large-scale production either on light-land arable farms, when the work will be done mainly by machinery, thus turning the farm labourer into an agricultural mechanic, or on strong-land grass farms—ranches, if you like—where the labour will consist entirely of stockmen and shepherds. If the economic status of the farm worker is to be raised it can only be by devising some system of organisation for production which will increase the value of his output. Taking, first, the case of arable farming, the impossibility of doing this on the great bulk of the existing units of production has been demonstrated already, but if you could separate your ploughman from his picturesque plough-team and give him the charge of an agricultural tractor, or of a steam engine, his daily output of cultivation would at once be increased to an amount which would justify the payment to him of wages comparable—other things considered—to that of the worker in urban industry. Such a metamorphosis would involve two great changes. First, there would have to be a further engrossment of holdings, a new enclosure movement, directed towards the creation of farming units large enough to give full-time employment to a steam ploughing set and a fleet of agricultural tractors. Two thousand acres of tillage would be the smallest working unit for such a system, and the upper limit might easily be five times as much. Second, there would have to be a considerable re-distribution of arable and grass land. Mechanical cultivation, to be effective and economical, is only possible on easily worked land, the kind of land, in fact, that can be worked, as it is said, any day of the year. On the more retentive soils, cultivation by steam engine, and even more by tractor, is limited to certain conditions as to dryness, and horse teams are essential to supplement the work of the machines. This at once reintroduces the very conditions from which this suggested development is the means of escape, for it lowers the value of the output of the unit of labour. There is much light plough land to-day which could be farmed more cheaply by the extended use of mechanical power, were it not for the fact that the farm unit is too small to justify the capital outlay necessary. Again, there are large areas of inferior light-land grazings which would give more employment, more produce, and more profit under tillage, if their cultivation in large scale units could be organised.

To be brief, the transition here projected is that there must be a movement to bring together all existing light-land arable farms and all the light-land grazings capable of being ploughed, in units large enough to admit of mechanical cultivation in the highest degree. It would call, probably, for radical change in the farm rotation, but this presents no obstacle, and the outstanding fact is that by raising the value of the output of the unit of labour it would raise the economic status of the farm worker at the same time. Moreover, the need for repair shops would create a demand for a staff of engineering mechanics,

whilst the scale of operations would admit of, or even require, departmentalization in the organisation which would provide the ladder for advancement which is so conspicuously absent on the small farming units of to-day, when a man of 21 has already reached his zenith.

Time does not admit of the full development of the proposal. Suffice it to say that this is no mere idea conceived after dinner in an easy chair. Many examples of this transition may be seen, particularly on the light chalk soils of the South of England. In one notable case, the nucleus of an enterprise extending now to some 10,000 acres, was a few derelict farms which had been abandoned by their occupiers during the depression of the 'eighties. The present controller of this great business saw the opportunity which his neighbours could not realise, and by throwing field to field and farm to farm he developed a system based on a small labour staff raised to the maximum efficiency by the free use of machinery, which has stood the test of good fortune and bad for forty years. Although there are signs that this system is spreading it cannot be described as popular, nor does it make an appeal to the lover of rural England as he has become accustomed to know it. Increasing the efficiency of labour in the attempt to justify higher wages involves a further depopulation of the countryside, and in districts where farming of this type is being practised derelict houses are common, and the country generally bears the aspect, to a certain extent, of desolation. It is a question of standards and ideals. Is it better to have two men tilling the soil by almost primitive methods for a reward considerably less than that of any other class of labour, or one man equipped by the application of all the inventions of modern science to do the same work for a more nearly commensurate wage? In spite of the decline of the agricultural population it is probable that there are to-day too many men engaged upon the land, and this intensification of labour is but another illustration of the application to agriculture of the law of diminishing returns. One man's production is worth so much; that of two men employed on the same area is worth proportionately less, and so on.

Nor does this system make for increased production. The extensive and somewhat rough-and-ready methods which it entails does not tend to make the best use of the land, measured quantitatively. But here, again, agriculture is up against the law of diminishing returns, and in the face of falling markets it is probably true that in many cases production from the land is being forced too far. The basis for the argument for the transition suggested here is that British agriculture has got to fall into line with other industries as regards the standard of comfort it affords to the workers engaged in it; and if this can only be achieved by the adoption of methods which result in a lower standard of productivity and in a reduction of employment, the sooner the facts are faced the better.

Now let us turn to the other direction in which this transition of agriculture may proceed—that of stock-farming on grassland. Much of the land of the

country is unsuited to the development of arable farming mainly by mechanical power. It has been pointed out that for work of this kind it is essential to start with land which can be tilled, if necessary, on almost any day of the year ; and some other system is needed upon soils of other types. The suggestion with regard to them is that they should be handled in considerable areas as stock ranches. This again would involve a considerable degree of engrossment of holdings, and the laying down to grass of much of the colder ploughlands. Here there is no opportunity for the utilisation of mechanical power and agriculture mechanics on any scale ; but the opportunity for the economic advancement of the labourer would come in other ways. In the first place an increase in the size of the general run of grass holdings would reduce the number of persons which they have to support. On many of the existing farms the work of management may be said to cease with the end of the summer grazing season, and not to begin again until the following spring. In this way it may be said that there are too many managers to be supported, and in general the conduct of operations on a scale much larger than that now customary would result in economies which could be reflected in the rate of wages. Apart from this, however, the stockmen and shepherds have always been the highest paid class of labour on the farm. The degree of skill and intelligence required of them is higher than that of their fellows, their hours of work are longer. Thus, whilst the opportunities presented by large-scale arable farming for raising the efficiency of labour are largely absent in the case of grass-ranching, it seems likely that the special conditions attaching to the work of a stockman and shepherd will secure for him that higher rate of remuneration which everyone must agree has got to come. The case for an increase of wages is not so strong as applied to this class of labour, for it has always commanded a higher reward ; but the transition suggested would lead to the laying down of much arable land which cannot be cultivated to do economic justice to the ploughman at the present level of commodity prices ; and, moreover, by a large scale organisation similar opportunities of advancement would be afforded, by division of labour and departmentalisation, which are impossible on the smaller grass farms of to-day.

Again it should be said that this is not an imaginary picture of what may come about, but that many examples already exist of farming on these lines. They, too, are not attractive regarded from the conventional standpoint of what farming should be. Derelict farm-houses and deserted villages make no appeal. But England has survived changes equally drastic in the past and may have to do so again.

I do not want to give the impression that I look forward to a time when the country will be divided between great arable holdings farmed by mechanics, and great grass ranches staffed by cowboys. The fertile fen-lands, the fruit-growing and market-gardening districts and other regions, possibly, where agri-

culture has already been industrialised, or where the land is abnormally productive, will work out their own methods of evolution. Nor do I expect the changes indicated as likely to be brought about in a short space of time. It took 100 years to effect the enclosure of the common fields. It required a generation to lay down four million acres of plough land rendered unprofitable during the agricultural depression. But if you are prepared to grant that agriculture can expect no favoured treatment from the State, whilst at the same time that it must organise itself so as to give those engaged in it a standard of life commensurate, at least, with that of their fellow-countrymen engaged in other industries, then I want to suggest that a transition in two directions such as those which I have briefly indicated is inevitable, and that much hardship and even suffering may be averted if we face the situation and prepare ourselves to meet it.

DISCUSSION.

THE CHAIRMAN said they had been privileged to listen to a very interesting and instructive address, as they might expect to receive from Mr. Orwin, who had already proved himself, in very many instances, to be a very close investigator into agricultural conditions. As Director of the Institute for Research in Agricultural Economics at Oxford University, Mr. Orwin had a special right to talk about the economic side of the question. He believed Mr. Orwin had even been bold enough to publish an agricultural policy—a policy which was of great interest and which he himself, certainly from one point of view, admired, because Mr. Orwin adopted a standard somewhat different from that which had been adopted in many other policies which had been put forward. He did not know whether it would have occurred to Mr. Orwin, as it had occurred to himself, and, he thought, to almost everybody who had been guilty of the offence of publishing an agricultural policy, that however much one might believe in it oneself, and however inclined one might be to think it would lead to the universal salvation of agriculture, yet no one of them had ever been able to get any large body of agricultural opinion to agree with him.

In dealing with the transition of agriculture, it was of great importance to study those conditions which had been operative in the earlier transitions which had been noted. The lecturer had led his audience with great skill through a number of those periods in which agriculture was obviously changing from one system to another. In previous centuries agriculture had often been in a state of transit. There had been from time to time what was being seen at the present moment, namely, a general attempt to convert corn lands into pasture lands. There were one or two things to be noted about that. First of all, in every case there was in such a transition a very large loss of capital both to the owner and to the occupier of land, and, secondly, the displacement of agricultural labour must in every case have a serious effect not only upon the district at the moment, but upon the future farming in the country, because when the agricultural labourer was once gone there was little or no possibility of getting him to return.

The agricultural industry had from time to time been subject—in fact, it was characteristic of the industry throughout all ages—to periods of depression, alternating with periods of prosperity. The difficulties under which agriculturists suffered were not by any means confined to this country. The same thing was found in

countries where conditions totally different from those in this country prevailed. In countries which were exporters of grain or meat, in countries which had high tariffs, in countries which were free importers—right throughout the world, there was the general complaint that the reward for labour and the return upon capital was less in the agricultural industry than it was in any other. That did suggest that we were up against a real world-wide difficulty in agriculture—a difficulty which could only be met by a world-wide remedy. Parliaments here and elsewhere were always busying themselves with agricultural legislation. Every year Statutes dealing with agriculture were put on the Statute Book, but they dealt largely with questions of land tenure, of the creation of small holdings, of the hours and remuneration of labour, and various matters of that kind. He believed that those well-meant and useful attempts could do little more than touch the real fringe of the difficulty until there was a more scientific knowledge of the foundation upon which that difficulty was based. One of the striking features of the present transition was the great advance in agricultural research, and the fact that the practical farmer of to-day was relying much more upon that agricultural research than he had ever done before. That research had taught a great many things. Research workers had done a great deal to probe all the mysteries of the soil, and had dealt with those elements which advanced or retarded plant growth. Those were things of the utmost value to the practical farmer and had enabled him to surmount many difficulties with which he had been faced. But, again, those appeared to him to be of a somewhat domestic nature, and did not touch the world-wide evil. The lecturer had said that we must change our system here and go in for large industrialised farms. That was very likely the direction which would be followed, but, again, was that a remedy for the much bigger difficulty which affected the whole world? The type of farm which the lecturer advocated was to be seen in the United States of America, but were agriculturists there much better off than they were in this country? Had not the American farmers been petitioning their Government to give them subsidies in order to get them out of their difficulties? and although he would not say for one moment that the direction pointed out by the lecturer was not that which agriculture in this country would tend to follow, yet he had some fear that it would not be a whole remedy for the world difficulty which he was suggesting.

THE RT. HON. NOEL BUXTON, M.P. (formerly Minister of Agriculture and Fisheries) remarked that the lecturer had suggested that the real trouble was going to be the unwillingness of the modern worker to put up with conditions which, as he gathered from the lecturer's view, were inevitably bad economic conditions. With the present prospects of farming prices, a solution of the difficulty was urgently called for. Was it entirely an economic trouble? Certainly the wage, if it could not be improved very greatly, would continue to make a farm worker very unwilling to stay in the country; but possibly it was not a purely economic condition which made him so unwilling. Was it not, in a very large part of England, partly on account of what might be called social conditions? It seemed to him, comparing what he had seen of villages abroad with villages in this country, that here there was an enormously greater amount of class distinction and, for the lower orders, class subordination. It was surely partly that which made the modern man—the post-war man—uncomfortable in the village? He had experienced freedom, he had seen the world, and he had been told that things were never again going to be what they had been before the war; but he found that in his village, although probably the owner was a new owner,

the conditions for him were not much changed. Personally he hoped that, in that respect, that was a condition which could be changed. Personally he felt that the lecturer's book pointed a way to removing such conditions, because the lecturer thought that on purely practical grounds public ownership could be vastly extended to the advantage of agriculture. He personally also felt that public ownership might contribute to the removal of class distinction to a great extent. He had been amazed, in visiting Farming Co-operative Societies in the Rhine Valley, particularly near Cologne, and also in Belgium, to see how cultivators of vastly different degrees of importance mixed together, and how workers felt no embarrassment in sitting down at committee meetings with owners of 500 or 600 acres; nor did the farmers see anything at all unusual in mixing with their inferiors with perfect freedom. In this country the great prevalence of ownership more or less for the pleasure of what he might call, for want of a better word, a semi-feudal position—the pleasure of owning land, and so on—and our tradition of class feeling, made that sort of mixing up in an easy way very difficult. Perhaps the author could state whether some sort of public ownership—either Crown ownership or College ownership which prevailed in places like Thorney, which had now ceased to be in any way a feudal place—prevented social conditions from being so obnoxious, and that the labourer was more content to stay. It would be very interesting to know if any objective evidence was available to show that, by removing such inequalities, the agricultural worker was more ready to stop on the land.

SIR DANIEL HALL, K.C.B., F.R.S. (Chief Scientific Advisor, Ministry of Agriculture and Fisheries), said he took it that the whole point of the paper was whether farming in the future could pay rates of wages comparable to those paid in other trades. The only answer was that it had got to do so, or else it would not continue. Farming in this country was so close to industry and commerce, and was too near outlets in other directions, that either it had got to pay sufficient wages to tempt men to stop on the land, or otherwise the men would go somewhere else. Quite recently he had had a remarkable instance of the sort of feeling which was prevalent in that direction. He had been talking to an old labourer and had asked him how he was getting on at the present rate of wage—3rs. a week. The man had replied, "I am not doing so badly, but there is our Jim on the railway who gets 6os. a week." There, although the old man admitted that he was not getting on badly as compared with the 15s. a week which he used to get, yet at the back of his mind was the feeling that his Jim was getting 6os. a week, and not doing anything like such good work as he himself was.

He might also mention that he was a Trustee of a charity which trained boys for the land and gave them a superior kind of education which made them, if they were not fit for better things, at any rate really first-class agricultural labourers. That Charity had been sitting recently in committee to elect boys, and had been considering the case of one boy, when suddenly the boy's aunt had burst into the room in a towering temper, saying, "I have come all the way from Birmingham to stop my nephew going on to the land. It is a dog's life on the land, and as long as I am fit to earn a penny, I am not going to allow a nephew of mine to go on the land." That was that lady's attitude towards the idea of land work, and that attitude was a very real one. His own conclusion was that sooner or later—and the sooner the better—agriculture would have to pay the higher wages demanded. Could it pay those higher wages? That was the fundamental

question. The representative mass of farmers would state that they could not pay them, and costing accounts, such as the lecturer had outlined that evening, had been put forward to show that they could not pay them. Was that true? There were three possible ways out of the difficulty. One was the political way—tariffs, alteration of land tenure, and so forth—but it was not for him to discuss points of that sort; he would prefer to come down to the actual things which were under the control of the farmer himself. First of all, was the farmer himself such a manager that he could readjust his business to pay higher rates of wages? It was well known that many farmers were sufficiently good managers to be able to pay higher wages and still be able to live, but it could not be demanded of any big group, like farmers, that they should all be supermen, and therefore it might be said that on the face of it such improvements in farm management could not be expected as would bring the whole group up to the level of the men at the top. Again he asked himself, was that quite true? Was it not possible to bring about a readjustment and readaptation? The whole of the later history of farming had dealt with the efforts of the farmer to cope with a constant rise in wage rates. Going back 150 years, one found that the wages of agricultural labourers in the south of England were, roughly, 7s. a week, and that the price of wheat was roughly what it was to-day—hovering between 50s. and 60s. That had been the sort of position—that a quarter of wheat at 56s. had paid for eight weeks' wages. Only a little time ago, one found Eastern counties farmers arguing that a half-quarter of wheat ought to pay a man's wages for one week, and that the whole difficulty of the then position was that a sack of wheat no longer paid for a week's wages. All over that period there had been a constant effort to readjust matters between what the farmer was getting for his produce and the price of labour; and the industry had to go on with that readjustment. In Canada a bushel of wheat cost the farmer about 9d. for labour, and he was paying 60s. a week to his labourers. In England a bushel of wheat cost about 1s. for labour when the farmer was only paying 32s. a week wages. That was the sort of readjustment which had been going on for over a century, and it had got to continue. There were possibilities of bringing in more machinery, and of better organisation to make the men more effective, and therefore able to earn the higher wages demanded.

There was one other point of view which had to be considered. Not only was more efficiency in management required on the part of the farmer, but more efficiency as a human being was required from the man. It was a very general complaint from farmers all over the country that the man of to-day was not giving as good work as he was 20 years ago, or even before the war. It could be seen from the accounts of any well-managed farm that any given operation took more man-hours to-day than it did in the past. That could, and should be, rectified, and it was in the hands of the farmer to rectify it. He had somehow to see that he was educating his men better in a technical sense. At present, boys upon farms were just allowed to grow up; they were not being taught how to do the common operations of the farm in the speediest and most able manner. There was an enormous margin of improvement to be got in the man himself. That could be obtained, not by slave-driving, but by putting him in the way of doing the work most efficiently in the minimum amount of time and with the minimum amount of effort. Farmers would have to work on those lines because, whether they liked it or not, they had to realise that if farming was to continue it would have to pay wages comparable to those prevailing in any other business.

MR. ALBERT WADMAN (of Priesthawes, Polegate) said reference had been made to the periods of deep depression through which the agricultural industry had gone, and when agricultural produce had been worth much less than it was now. Why was it, if the industry could survive those periods, it could not continue to-day, when prices were better than they had been then? In his opinion the reason was that formerly there had been three parties connected with agriculture—the landlord, the farmer and the worker, and they had all been accustomed to work for little or nothing, but they had pulled together in one interest. The landlords used to help the farmers on every possible occasion, and used to keep their houses over their heads, and the farmers carried on until the law of supply and demand came round again in their favour and things began to right themselves. Why did not landlords do that sort of thing now? It was because they were not allowed to by the uneconomic conditions from which they were suffering. These conditions might be due to national necessities, and if so, he had nothing more to say. The nation had to come first and the farmer afterwards, but there should be no misunderstanding as to what the troubles were. They had to meet now health insurance, accident insurance and rising wages. The latter had been stated by Sir Daniel Hall as 31s. a week. Without fear of contradiction, he could say personally that while 31s. was a so-called minimum, it was a minimum which applied in very few cases indeed. The great majority of farm labourers were getting between 40s. and 50s. a week. He himself had farmed during the worst periods of depression. He had been concerned in carrying on eight farms at a time, and he had managed to pull them all through successfully. He was now concerned in the business in a large way, and he could not now pull one farm through. His audited accounts showed that his profits were nil, with no allowance being made for his energy, skill and intelligence. He thought it was well on occasions such as the present that those interested should not be afraid to approach the Government. Some of the agricultural representatives at present were in a position of somewhat partial ignorance of the situation. He was firmly convinced from his connection with other farms that farmers were making no sort of rent and were not paying their way.

MR. G. DALLAS (Secretary, Agricultural Workers' Union) said it was a very great pleasure to him to have heard Mr. Orwin's lecture. Mr. Orwin and himself had been concerned in one of the greatest pieces of constructive work which had been done in regard to agriculture. Although he did not always agree with Mr. Orwin, he had a very great and profound admiration for the scientific way in which he examined problems connected with agriculture, and his lecture that evening was only one instance of the scientific attitude of his mind towards agriculture. In past times there had been a very great gulf between the town and the country. One of the great factors in bridging that gulf had been, first, the schoolmaster, then the bicycle, then the omnibus and then the war, and there had been created in the country worker's mind the desire for the same standard of life as that which his city brother obtained. There was a great desire for a very much higher standard of living in the minds of the agricultural workers than used to be the case in times gone by, and that feeling would not be minimised in the slightest degree in the future. He had had his attention drawn quite recently to an instance of what was taking place in that regard, and what might take place in the future on a very large and wholesale scale. For a number of years past the country had been going through a very great industrial depression with anything from a million to a million-and-a-half people unemployed. Even during that time he had come

across two instances in two separate counties when, at particular times of the year, farmers had had to obtain men from the workhouse in order to carry on the work of their farms. If, therefore, the country was fortunate enough to come suddenly and rapidly into a period of industrial prosperity, when unemployment would largely disappear, then he ventured to suggest that farmers would be faced with the greatest possible difficulty in obtaining the necessary workers. There would be a great exodus of men at present on the land into other pursuits which offered a higher standard of life.

As to the remedies for such difficulties, he was in the hands of experts like Lord Clinton and Mr. Orwin. He certainly did agree, however, from his own observations, that any development of small holdings would not in any way solve the problem with which he and the people he represented were concerned. There were, of course, a type of people who would work all hours of the day and night if they were working for themselves—if they had no boss or anybody to direct them or order them about; but he ventured to say that that type represented a very small and probably a decreasing number. Personally he thought there was another avenue of approaching the problem. He thought there was growing up, not so much in this country as elsewhere, a recognition on the part of agriculturists that those engaged in producing agricultural products, however vitally important to the nation these might be, were not able to obtain the standard of comfort which people in less important industries got out of their labour and their capital. In May of the present year, in Kansas City, there was going to be held a great conference of agriculturists from Canada, America, the Argentine, South Africa, Australia, India and Russia. Those people were going to gather together with the object of considering that very point, as to whether those engaged in the industry as producers of foodstuffs were getting a fair return for their labour and capital. He might mention that in Western Canada a most interesting development had taken place. At least 80 per cent. of the grain which was grown there went into a farmers' pool. The farmers had cut out all the people who in some cases had performed useful functions and in other cases had performed no useful functions, and the speculator who had come between the producer and the consumer had been completely eliminated. That system of pools, which was growing up in the Dominions, was an action, in his judgment, on the part of producers to get a better and fairer return for their labour and their capital than they had hitherto obtained. He thought that possibly that would have a profound influence on the agricultural industry even of this country.

MR. R. BORLASE MATTHEWS, A.M.Inst.C.E., M.I.E.E., remarked that he was particularly interested in mechanisation, and the conclusion he had come to was that one very great factor in solving the problem was the use of electricity on the land. All over the world it was found that the more successful nations were succeeding because each of their workmen had more power at his elbow, and one of the things which farmers had to get was more power at the elbow of their men. If they could do that then there would be an opportunity given them of increasing the wages of their men, of increasing their own profits and of producing cheaper food. That necessary power had got to cease to be composed very largely of animal or man power; it had got to be mechanical power, and of all forms of mechanical power electrical power was, in his opinion, going to be of the greatest advantage. Unfortunately, through early Parliamentary legislation and the fact that this country was one of the pioneers in supplying electricity, electricity was being greatly hampered in its spread in this country more than in any other part of the world. The new Electric

Supply Act was almost entirely an urban Act and was not directly going to benefit the country at large. It simply dealt with the cheap generation of power and did not cover the distribution of it. One of the steps which the farmers of this country would have to take would be to see that electric current was rendered available for distribution over the land. He was not suggesting that electricity should be used because it was electricity, but simply because it was a power which could be rendered more available at a cheaper rate than any other power, and because it was an extremely convenient form of power to use.

There was also the question of auxiliary industries, such as the brewing of beer, the manufacture of alcohol, mechanical work, etc., which might well be linked up with general farm work, and if ample power was available it would facilitate the establishment of such auxiliary industries. Altogether, he thought that if electricity were distributed and made available over the whole country-side, it would greatly reduce the costs to farmers and generally facilitate and improve their position.

LORD HENRY BENTINCK, M.P., in proposing a hearty vote of thanks to Mr. Orwin for his lecture, said that Mr. Orwin was a gentleman at whose feet every farmer was delighted to sit, because they all knew that he combined science with practice. He would like to ask Mr. Orwin how it was that tractor machinery upon the land had almost died out. It had been very prevalent during the war, but one hardly saw now a machine in operation. He supposed it was owing to the inefficiency of the man who worked the machinery; he had not been trained as a mechanic. Nobody held Mr. Orwin more in admiration than himself, but he had been rather appalled at the prospect which Mr. Orwin had described. He had given a very gloomy picture of derelict villages, farm buildings, and so on. Personally he could not help feeling that the nation would have to make up its mind that those who were engaged on the land were deserving of a more decent standard of life than had hitherto prevailed, and that it would have to frame its policy accordingly. He thought that if the subsidy had been continued all throughout these years it would not have been a very serious burden upon the nation. He came from a part of England where no subsidy was needed, where the farmers themselves and their families all turned out and worked. That was the principle which he should desire to see carried out in this country, and it was the principle by which he thought the storm would be weathered. It was really much more to the national interests, and to the interests of humanity as a whole, that the system should be carried out rather than agriculture should be turned into a system of robotism.

MR. JAMES CAWSON, in seconding the motion, asked if Mr. Orwin would explain how Denmark was such a prosperous agricultural country. The Danes seemed to be able to succeed in agriculture in a very remarkable way.

The vote of thanks was then put and carried unanimously.

MR. ORWIN, in reply, said there was nothing really for him to say as everybody seemed to agree that the rate of wages in the agricultural industry had got to be levelled up to that paid in other industries; and that had been the whole basis of his remarks. For the rest, he had been simply prophesying as to how he thought it might be done. Personally he hoped that it would be done by the method suggested by Lord Henry Bentinck, but he did not see how those conditions could prevail indefinitely in the face of the other and easier conditions which prevailed in other forms of industry.

In reply to Mr. Cawson's question, the Danes succeeded simply on account of their lower standard of living. There were no industries competing with agriculture in Denmark, and if the people did not farm their only alternative was to starve.

MR. A. W. HUNTER (General Secretary, National Farmers' Union of Scotland) writes :—"One notable omission in the paper is any reference to better methods of marketing. One cannot help thinking that Mr. Orwin should have told us how far, in his opinion, the present difficulties may be overcome by simpler methods of marketing, and the sweeping away of the hosts of those nondescript 'Merchants' and 'Dealers' who batten on the producer and consumer."

COMMERCIAL SITUATION IN FORMOSA.

Though Japanese firms and residents in Formosa are still complaining of hard times, there can be no doubt, writes H.M. Consul at Tamsui, that the island, dependent as it is mainly on agriculture, has never been more prosperous, and that the Chinese peasants, who form nearly 90 per cent. of the population, are exceedingly well off. This favourable result is principally due to the large crops of rice harvested in recent years and sold at high prices, and to the enormous development of fruit crops, such as bananas, pineapples, oranges, etc., for export to Japan. In other respects also, this most remarkable dependency of Japan continues to make progress. The production of sugar, though suffering from the inroads of rice cultivation and of rather doubtful benefit to the agriculturalist, is well maintained; the output of coal has approached 2,000,000 tons, and both exports and bunkers increase year by year; pouchong teas continue to find an expanding market in Southern Asia, though the oolong tea trade appears to have seen its best days; the camphor industry affords a large source of revenue to the Government. It even appears possible, from results obtained during recent months, that Formosa may prove a source of oil supply in the future.

As is natural in a highly productive agricultural island, fertilisers constitute the largest import, bean-cake and sulphate of ammonia being by far the most important descriptions. Bean-cake is obtained from China, and is extensively used on both rice and sugar lands. It is only a few years since sulphate of ammonia was first introduced on sugar plantations in Formosa, but in 1925 imports had reached 30,000 tons, valued at 5,546,000 yen (yen=2s. 0½d.), the corresponding figures for 1924 being 10,600 tons, valued at 1,825,000 yen. It seems probable that the statistics for 1926 will show a further large increase. In 1924 the United Kingdom supplied nearly 75 per cent. of the total imports, but Germany entered the field in 1925 and, during the first four months of 1926, supplied over 9,000 tons, against 5,500 tons from the United Kingdom.

At present this class of fertiliser is only used on sugar plantations, but it is probably only a matter of time before it is adopted for rice lands, and *imports may then rise to very large figures.*

Rice now occupies the second place in the lists both of imports and exports. The production and export of rice in 1924 and 1925 are shown below :—

					Production.	Export.
					Bushels.	Tons.
1924	..	..	..	..	36,137,000	253,600
1925	..	..	..	..	31,967,000	330,800

Two crops are produced annually. Exports are all to Japan.

The most interesting feature in regard to rice is the recent discovery that the

Japanese species can be raised successfully in Formosa. Hitherto the Japanese have regarded Formosan rice, like all other imported rices except that from Korea, with distaste, but this new rice—grown from Japanese seed—is said to be almost identical in taste with that produced in Japan itself. The farmer obtains for the new rice prices nearly 40 per cent. higher than for the ordinary Formosan grain, though production expenses are only slightly larger. It follows that the growing of this Japan species rice has been adopted with great enthusiasm, and, notwithstanding the fact that production was only seriously commenced in 1923, nearly 30 per cent. of the available ricelands of Formosa were planted with it for the 1926 first crop.

One result of this new development is already apparent in the increased import of Rangoon and other foreign rice for island consumption.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, MAY 23. Aeronautical Engineers, Institution of, at the Royal Society of Arts, Adelphi, W.C. 6.30 p.m. Mr. S. A. Main, "Heat Resisting and Non-Corrosible Steels."

Architects, Royal Institute of British, 9, Conduit Street, W. 8 p.m. Mr. Arthur J. Davis, "The Moorish Architecture in Northern Africa."

East India Association, at Caxton Hall, Westminster S.W. 3.30 p.m. Lieut.-Colonel Sir Francis Young-husband, "The Exploration of the Himalaya."

University of London, at King's College, Strand, W.C. 5.30 p.m. Don Américo Castro, "Lope de Vega comme représentant de la vie et de la sensibilité de l'Espagne." (in French). (Lecture I).

5.30 p.m. The Principal of King's College, "Some Modern English Historians." (Lecture IV). "Stubbs."

5.30 p.m. Mr. Henry Wickham Steed, "Hungary and Jugo-Slavia."

At the London School of Economics, Houghton Street, Aldwych, W.C. 5 p.m. Mr. G. V. Portus, "Political Theory and Economic Experimentation in Australia." (Lecture II).

At the London School of Medicine for Women, 7, Hunter Street, W.C. 5.30 p.m. Prof. H. Beckwith Whitehouse, "The Menstrual Function, its Physiology and Pathology." (Lecture II).

TUESDAY, MAY 24. Photographic Society, 35, Russell Square, W.C. 7 p.m. (1) Dr. Frances Hamer and Mr. Olaf Bloch, "The Chemical and Photographic Properties of a series of typical Cyanine Dyes; (2) Messrs. H. Mills Cartwright and F. J. Tritton, "Inherent Fog in Photogravure Resists and a Method for its Elimination."

University of London, at King's College, Strand, W.C. 3 p.m. Prof. Dr. R. J. S. McDowall, "Autonomic Nervous System." (Lecture IV).

At the Royal School of Mines, South Kensington, S.W. 5.30 p.m. Dr. F. F. Blackman, "Problems of the Respiration of Plants." (Lecture III).

At University College, Gower Street, W.C. 5.30 p.m. Mr. W. H. McLean, "National, Regional, and Town Development Planning." (Lecture III).

WEDNESDAY, MAY 25. Egypt Exploration Society, at Burlington House, W. 8.30 p.m. Prof. P. E. Newberry, "Sais."

Geological Society, Burlington House, W. 5.30 p.m. Dr. F. S. Wallis, "The Old Red Sandstone of the Bristol District"; Prof. Sampat Iyengar, "Cretaceous-Reptilian Vertebra from Southern India."

University of London, at King's College, Strand, W.C. 1.30 p.m. The Rev. Canon E. S. Woods, and the Rev. Canon V. Storr, "The New Prayer Book." (Lecture III).

5.30 p.m. Mr. Arundell del Ré, "Some Italian Impressions on the Court of King James I."

At the London School of Economics, Houghton Street, Aldwych, W.C.2. 5 p.m. Mr. C. S. Orwin, "The Economics of Agriculture." (Lecture II).

5 p.m. Dr. Hubert Hall, "Housekeeping in Six Centuries (1200-1800)." (Lecture V).

At the School of Oriental Studies, Finsbury Circus, E.C. 12 noon. Mr. T. A. H. Way, "Indian Administrative Law." (Lecture V).

THURSDAY, MAY 26. British Science Guild, at the Royal Society of Arts, Adelphi, W.C. 3.30 p.m.

University of London, at King's College, Strand, W.C. 5.30 p.m. Don Américo Castro, "Lope de Vega comme représentant de la vie et de la sensibilité de l'Espagne." (in French). (Lecture II).

At University College, Gower Street, W.C. 2.30 p.m. Prof. Dr. Sir Flinders Petrie, "Recent Discoveries in Palestine: the City of Gerar."

FRIDAY, MAY 27. Physical Society, at the Imperial College of Science and Technology, South Kensington, S.W. 5 p.m. (1) Dr. Ezer Griffiths, and Edgar Griffiths, "A Duplex Reversal Key with Mercury Contacts."

(2) Mr. L. Hartshorn, "The Measurement of the Inductances of Four-terminal Resistance Standards."

(3) Dr. C. Chree, "Magnetic Disturbances and Aurora as observed by the Australian Antarctic Expedition at Cape Denison in 1912 and 1913." (4) Mr. K. R. Reo, "Series in the Spectrum of Trebly-ionised Tin (Sn. IV)." Mr. G. L. Addenbrooke, "Demonstration of the Production of Splashes by Electric Discharge."

Royal Institution, 21, Albemarle Street, W. 9 p.m. His Excellency the Marquis de Merry del Val (Spanish Ambassador), "Gabriel y Galan, Contemporary Spanish Poet."

Sociological Society, at Burlington House, W. 8.15 p.m. Miss Amelia Defries, "The Origins and Social Significance of the Harlequinade and the Commedia dell'Arte."

University of London, at Guy's Hospital Medical School, St. Thomas's Street, S.E. 5.30 p.m. Prof. Dr. E. H. Kettle, "Inflammation and Infection." (Lecture II).

At King's College, Strand, W.C. 5.30 p.m. Monsieur Denis Saurat, "Marcel Proust." (in French). (Lecture II).

5.30 p.m. Dr. Edwyn Bevan, "Ancient Theories of Inspiration."

At the London School of Economics, Houghton Street, Aldwych, W.C. 5 p.m. Mr. Philip Noel Baker, "The Economic Conference held at Geneva, May, 1927." (Lecture I).

At University College, Gower Street, W.C. 5.30 p.m. Prof. Dr. John Burnet, "Platonic Problems." (Lecture III).

SATURDAY, MAY 28. Arts, League of, at the Victoria and Albert Museum, South Kensington, S.W. 3 p.m. Mr. J. Clifford Turner, "Selections from Classic and Contemporary Poets."

University of London, at University College, Gower Street, W.C. 3 p.m. Prof. Dr. Sir Flinders Petrie, "Recent Discoveries in Palestine: the City of Gerar."

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FRIDAY, MAY 27th, 1927.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2.)

NOTICES.

NEXT WEEK.

TUESDAY, MAY 31st, at 4.30 p.m. (Dominions and Colonies Section.)
SEÑOR DON TOMAS BALDASANO, LL.D., Caballero de Isabel la Católica,
London Correspondent of La Epoca, Madrid, "Spanish Morocco." THE
RIGHT HON. THE EARL OF SELBORNE, K.G., P.C., G.C.M.G., will preside.
Tea will be served in the Library from 4 o'clock before the meeting.

TWENTY-FIRST ORDINARY MEETING.

WEDNESDAY, MAY 18TH, 1927. SIR ROBERT A. HADFIELD, Bt., D.Sc.,
F.R.S., Vice-President of the Council, in the Chair.

The following candidates were proposed for election as Fellows of the
Society :—

Cameron, Barton H., Gordonsville, Virginia, U.S.A.
Hardy, George F., Sc.D., B.S., New York City, U.S.A.
Shankar, Kunwar D., Fatehpur Sikri, Agra, India

The following candidates were duly elected Fellows of the Society :—

Bishop, Walter Frederick Enfield, Middlesex.
Hedgcock, Archibald John, Purley, Surrey.
Keay, George Edmund, Birmingham.
Potter, William Joseph, London.
Pratt, Major James A., Delaware Co., Penna., U.S.A.
Rosling, Percy, Shortlands, Kent.
Salmon, Arthur Edward, Bourne End, Bucks.
Sherman, William G. Matthews, Brimsdown, Middlesex.
Weidlein, Edward Ray, M.A., Sc.D., Pittsburgh, Pa., U.S.A.

A paper entitled "Industrial Welfare in Great Britain and the United
States" was read by Mr. ROBERT R. HYDE, Director of the Industrial Welfare
Society.

The paper and discussion will be published in the *Journal* dated July 22nd.

PROCEEDINGS OF THE SOCIETY.**DOMINIONS AND COLONIES SECTION.**

TUESDAY, MARCH 29TH, 1927.

SIR MICHAEL E. SADLER, K.C.S.I., C.B., Master of University College,
Oxford, in the Chair.

THE CHAIRMAN, in introducing Mr. J. H. Oldham, said that he was the Secretary of the International Missionary Council and a member of the Advisory Committee on Native Education in Tropical Africa, which was set up in 1923 at the Colonial Office by the Secretary of State, and of which at the present time Mr. Ormsby-Gore acted as Chairman. The keynote on the administrative side of the paper to be read that evening was the value of co-operation, the joint working together for the good of the people of the many agencies, political, religious, administrative, technical, which played so great a part everywhere in the Commonwealth. Very much of the spirit of co-operation which now prevailed was due to the author's indefatigable work and wise influence. To his insight and patience, his first-hand knowledge of the facts and fairness of judgment all who cared for the future of tropical Africa were greatly indebted.

The following paper was then read :—

RECENT TENDENCIES IN AFRICAN NATIVE EDUCATION.

By J. H. OLDHAM,

Secretary of the International Missionary Council, and Member of the
Colonial Office Advisory Committee on Native Education in
Tropical Africa.

The notable increase of interest in the problems of education in Africa during the past few years is the result of a general awakening to the importance of the human factor in the development of the continent. The European occupation of Africa, so far as nine-tenths of the continent is concerned, is an event which has taken place within the life-time of the present generation. In the early years the main energies of those responsible for the administration of African colonies were necessarily engaged in the preliminary work of exploration, of opening up communications and of establishing a framework of law and order. The partial accomplishment of these tasks allows those responsible for guiding the destinies of the continent to take fresh stock of the position, and when this is done it becomes increasingly plain that the future of Africa, from the economic, as from other standpoints, depends on the African. Neither in numbers nor in physique, nor in intelligence, as Mr. Amery has reminded us, are the peoples of Africa at present capable of meeting the demands which the new conditions make on them, and consequently "the duties of statesmen lie in the physical, moral and intellectual development of the Africans." If Mr. Amery is right in regarding this as one of the primary duties of statesmen, it is not surprising that education, in the broadest sense of the word, should assume a new place of importance in the African programme.

Practical expression was given to this conviction by the action of the Secretary of the State for the Colonies in appointing in 1923 a standing Advisory Committee on Native Education in Tropical Africa. There is now in existence at the Imperial centre of colonial administration a body definitely charged with the duty of giving thought to the human factor in the African problem. Machinery has been set up which makes it possible to study as a whole what is being done in the different colonies, to keep them in touch with one another in the formulation of their policies, to call to aid the best expert advice that the Empire can provide, to follow experiments in other parts of the world in the education of backward races, and to promote co-operation between the Government and the missions, Roman Catholic and Protestant, in whose hands is the conduct of by far the greater part of native education in Africa. The institution of the Committee was due largely to the enthusiasm and statesmanship of Mr. Ormsby-Gore, and his able Chairmanship has contributed greatly to the success which has attended its work in these early years. This is only one of the many services which Mr. Ormsby-Gore, as Under-Secretary for the Colonies, has rendered to the Empire. It is not without interest that the conference at which the decision was taken to recommend to the Secretary of State the establishment of the Committee, and which was attended by five Governors of African colonies, one ex-Governor and one Colonial Secretary, was held on Derby Day, which suggests that African education is capable of vying in attraction with the most famous of horse races. Of greater significance, perhaps, is the fact that at a time when the Geddes axe was ruthlessly reducing the ranks of civil servants, African education was judged to be of sufficient importance to justify the creation of a new post, and the Advisory Committee was given a whole time secretary in Major Vischer, without whose energies its opportunities of service must have been greatly restricted.

By a fortunate coincidence, at the very time when a new interest was beginning to be aroused in this country in the problems of African Education, a highly stimulating and suggestive contribution to the subject was made from America. The United States has had its own problem of Negro education which was thrust upon it half a century ago by the sudden emancipation of the slaves. In trying to cope with the situation it had the good fortune to find an educator of originality and genius in General Armstrong, the founder of Hampton Institute, who had himself the good luck which does not fall to every great educator, to have in Dr. Frissell a successor to carry on his work scarcely less able and gifted than himself, and in Dr. Booker Washington, a pupil who attained to similar eminence. Through the genius of these remarkable men applied to the novel problems presented by the education of a race of freed slaves many fresh insights into educational principles and methods have been won which have enriched educational theory and practice, not only in America, but in other parts of the world.

Few men have a wider acquaintance with the experience and lessons of

American Negro education than Dr. Thomas Jesse Jones. A teacher for some years in Hampton Institute, he undertook during the years 1913 to 1916 a thorough survey of Negro education in the Southern States, the results of which were published in two large quarto volumes by the Bureau of Education connected with the Department of the Interior at Washington. A few years later the Phelps-Stokes Fund, of which Dr. Jones is the Director, took the initiative in arranging for an Education Commission, of which he was the Chairman, to visit West Africa and South Africa. This visit took place in 1920-1. In 1924 the survey of education in Africa was completed by a second Commission which visited East Africa. The Reports of these two Commissions appearing, as they did, at the right moment, have given a definite direction to thought about African education. Educators, whether in Government or in missionary service, and administrators, have been quick to recognise the value of the ideas contributed by these Reports.

If the attempt were made to describe the essence of Dr. Jones' educational philosophy in a sentence it might perhaps be put thus. One of the great changes in modern education has been the gradual shifting of the primary emphasis from subject matter to the child. Professor Adams has illustrated the change by the two accusatives in the Latin sentence, *Magister Lalnam Johannem docuit*. The old teaching laid the chief stress on Latin; the new teaching lays the chief stress on John. What Dr. Jones is especially anxious to say is that there must be a further advance. It is not enough to relate our teaching to the needs and capacities of John regarded as an isolated individual; the whole of education must also be conceived and planned with direct and conscious reference to John's environment. As a result of this conviction the discussion of education in every colony visited by the Phelps-Stokes Commissions is introduced by a chapter dealing with the economic and sociological background.

Approaching the subject of education from this standpoint, Dr. Jones lays primary emphasis on what he calls four essentials of education. His claim is not that these are the only essentials of education, but that they are necessary ingredients in any sound educational system. These four essentials are, first, health; secondly, appreciation of the environment, material and human, and alertness on the part of the educator to the potentialities of land and people, which in African conditions means special attention to agriculture; thirdly, the care and strengthening of the family, which is the bond of continuity between one generation and another; and fourthly, recreation and the right use of leisure. What Dr. Jones proposes in insisting on these essentials is not, of course, the substitution of courses on hygiene, or agriculture, or the family for the more usual school subjects, but rather that the teaching of the ordinary subjects should be directed and inspired by a proper regard to these realities of African life, e.g., that use should be made of school readers and of the teaching of elementary science to create a better understanding of the laws of health;

and still more that the practice and example of the school should be made a means of fostering a right attitude towards health, sanitation, agriculture and the family.

It is impossible in this paper to follow out in detail this programme of education. It is worked out with great fullness in the Reports of the Phelps-Stokes Commissions. A further brief reference may be made, however, in passing to the first essential of health. No one acquainted with African conditions can question that the fundamental problem of the continent is health. The population of the greater part of tropical Africa is sparse, and there is reason to fear that in some parts it may actually be decreasing. It is clear, further, that in a campaign against disease two of the most important points of attack are the improvement of diet and the betterment of living conditions. In a health campaign which has these objectives, a more effective instrument for carrying on the campaign could hardly be found than is supplied by the tens of thousands of little village or bush schools, largely under mission auspices, scattered throughout the continent. In equipment and teaching capacity they may amount to little judged by western standards; but as centres of propaganda for new ideas regarding health and sanitation they offer endless opportunities. In them health education on the simplest lines can be imparted as an integral part of the daily curriculum, in regard to such matters as housing, food, personal and moral hygiene, general sanitary habits and simple measures against prevailing diseases. The strongest emphasis was laid on this function of the village school at the international Conference on the Christian Mission in Africa held in Belgium last September, and it may be hoped that as a result health education will be given a new place in mission schools throughout Africa.

It is not surprising that the conception of education which has been outlined should have made a strong appeal to administrators. The attitude of political officers towards education has, in Africa, as elsewhere, in many instances been one of indifference and distrust, sometimes of opposition. The distrust has not been without grounds. What has sometimes been proffered in the name of education has not been of a nature to inspire confidence. It has too often given only a smattering of knowledge while it has at the same time weakened the old restraints or sapped the old loyalties. Its products have become detached from what was soundest in the old life, without being fitted to play any effective part in the new conditions. Not a few administrators have discovered with surprise and pleasure—though there are doubtless others who are still unaware of the change that is taking place—that the aim of the best educators, however difficult and distant its full realisation may be, is to serve those purposes which lie nearest to the heart of many political officers, namely, the physical and social advancement of the people who are under their care.

Nothing that has been said is intended to suggest that the ideas which the Phelps-Stokes Commissions brought to Africa are entirely new. The ready acceptance they have found is evidence that the minds of African educators

were already prepared to welcome them. Almost everything the Commissions have advocated was already to be found in operation in some part of Africa. The service which they have rendered has been to crystallise ideas that were floating vaguely in the minds of many people, and to give a powerful impulse to tendencies that were already beginning to make their influence felt.

It is important, in order to prevent possible misunderstanding, to note that there is nothing in the programme which has been described that imposes or implies any limits on the African's educational progress. The Advisory Committee, in their memorandum on educational policy, say quite definitely that, "as resources permit, the door to advancement through higher education must be increasingly opened for those who, by character, ability and temperament, show themselves fitted to profit by such education." The Prince of Wales' College at Achimota, which is the nucleus of a West African University, is conclusive evidence of the desire of His Majesty's Government that no limits should be set to the educational advance of the peoples of Africa. But the immediate task throughout the greater part of Africa is to lay sure foundations for future progress in a sound and wide-spread system of elementary education and in the improvement of economic conditions and of the economic capacity of the masses of the people.

One of the most interesting attempts to carry out the type of education which has been described is being made at the Jeanes School in Kenya. This school, which has been established for the purpose of training visiting or supervisory teachers for village schools, is an outcome of the visit of the Phelps-Stokes Commission to East Africa. American experience in Negro education in the Southern States and in the Philippines has shown that in the education of a backward race, where the only teachers to be had have themselves had only a minimum of schooling and are poorly trained, good results can be obtained notwithstanding these drawbacks on the one condition that the teachers are not left entirely dependent on their own resources. The plan has consequently been evolved of selecting teachers who have shown special capacity, giving them a further period of training and then putting them in charge of a little group of a dozen or twenty schools, which they visit at frequent intervals, remaining for half a day or three or four days, as circumstances may require, showing the teacher how he may do his work better, and returning again after a few weeks to see whether the improvement has been maintained and to help him forward another stage. The Jeanes School is an experiment in Africa on similar lines.

The second distinctive feature of the Jeanes School is the attempt which is being made in it to evolve a new type of curriculum adapted to the primary needs of African village life. In the two years' course the teachers receive further instruction in the teaching of the conventional subjects, but in addition to this much time is devoted to simple health education and to practical instruction in the growing of crops, the building of better houses and the general improvement of village life.

An idea of what the School is attempting to do can perhaps best be conveyed by reproducing a letter written, not by the visiting teachers undergoing the full course of training, but by a group of ordinary village teachers who had been brought to the School for a special one month's course of additional training. It shows that these raw and simple village teachers had caught at least a momentary glimpse of a broad and rich conception of what education means. The letter written in the vernacular and translated by the Principal runs as follows :—

“ We are very glad that we were invited to attend the Jeanes School to be taught the best ways of teaching and the best things to teach. We are thankful that the Jeanes School is here in our country, for it will bring progress to our people. We beg the Government to be good enough to bring Village Teachers for a course like this every year. If we had fifty teachers at the Jeanes School once a year, our schools would soon begin to wake up and our people too.

We now wish to thank those who kindly came here to teach us in the middle of their own work, and those who enabled them to come : —

1. The Director of Education, because he came to the School and showed us which is the most important matter among these three : (a) TO DO ; (b) TO KNOW ; (c) TO SAY.

2. The Director of the Medical Department who let us see the best ways of preventing disease and who showed us, in the Museum at Nairobi, the dangerous animals which cause disease. We saw these things openly. We wish to thank him especially because we saw the Native Hospital. We are so glad to know that the Government are our friends, and we thank both the European doctors and the native dressers for showing us so many things, more than we can count.

3. The Director of Agriculture, because, through his kindness, we learnt how to plant seeds, to cultivate the ground and to grow good crops. We saw many good things at the Scott Laboratory, and we learnt that there are many plants native to Kenya which we can use along with foreign plants. We will teach our pupils these things.

4. Mr. ——— deserves our best thanks because he came here with some of his pupils, and he taught us that we must not forget our good traditions, such as pottery, songs and stories. We know that a tree without roots cannot stand.

5. To Mr. ——— and Mr. ——— we say thank you, because they came here in their kindness and taught us how to drill, so that we may make our own bodies strong, and also teach our scholars what they taught us.

6. Miss ——— was specially kind, for she taught us a most excellent way to teach young children. We thank her that we were able to understand her teaching method. If we can follow her lessons in our own teaching, we will bring our pupils forward quickly.

7. To the Principal we wish to express our thanks for the kindness we received here and for the clean houses and the posho and firewood which could be bought.

We thank him for his teaching, and for showing us the dangers that meet us if we neglect the proper foundation of the people, and the only way by which we can multiply, viz., by health and cultivation of the soil. We also were taught to help our poor people and the elders and the women. He

taught us some secrets that were a surprise to us, such as the origins of the common things we use nowadays.

8. We should like to thank Miss —— for her inspection of the houses and for showing us how to be clean and tidy.

Yours most respectfully,

TEACHERS OF OUT-SCHOOLS.

P.S.—We do not want you to think when you read this letter that it is written simply to please. These thanks are in our hearts."

From this interesting experiment in Kenya, which is attempting to solve the problems of the little village or bush school, we may turn to Achimota in the Gold Coast, which is the beginning of a West African University, though it will be a few years before the pupils will be ready for the opening of university classes. Attention might be directed to many interesting features of this significant undertaking, but there is time to refer only to one which is of vital importance. The deliberate aim of Achimota is to bring about a living and organic relation between the new western knowledge and the African's own traditions and culture. The College has been established to give to Africans access to the rich storehouses of European civilisation and modern science. The academic standards aimed at will be the standards of European universities. Free access to the sources of western knowledge is indispensable if Africans are to participate in the economic and social development of their country. But what is needed for true national progress is not that a limited number of individuals should acquire an alien and exotic culture, but that under the stimulus of contact with a more advanced civilisation and with the help of modern science Africans should develop their own cultural heritage and create a civilisation expressive of their own native genius. "The true aim of education," as has been well said, "should always be to cultivate in individuals a feeling of love towards their tribe, but never to draw them away from the national body." The peoples of India and China are rightly beginning to revolt against a western education which takes no account of their own national traditions, and Africans equally have a right to be allowed to develop along their own distinctive lines.

But the problem which confronts the western educator in Africa is far more difficult than in India or China. These countries possess an ancient and rich civilisation. Society is more stable and better able to resist sudden change than in Africa. If the introduction of western knowledge is not to have a disintegrating and disastrous effect on African society a powerful effort must be made by educators to develop respect for the valuable elements in the African's own heritage. Such an effort is being made at Achimota. The study of the vernaculars, which are the medium through which the soul of a people expresses itself and the door to an understanding of its culture, is being encouraged. Careful attention is being given to the study of native music, art, folk-lore and history, and these are being used as the basis and groundwork of education. The aim is to create in the minds of Africans respect for their

own heritage and their own institutions, so that they will feel at home in the culture of their own race and be inspired with a desire to develop it along lines distinctively their own. It is hoped that by this means something may be done to prevent the products of western education from becoming what the French call *déracinés*, persons who merely ape and mimic the ways and habits of an alien race, because they have been unable to strike their roots in the natural soil of a living and developing native society. The objective which Achimota has set before itself is to turn out pupils who, on the one hand, understand their own people—their history, their traditions, their institutions and their prejudices—and, on the other hand, are able to comprehend the nature of the new forces, that are bringing about rapid and revolutionary changes in native life, and through comprehending them to escape the dangers and to seize the opportunities that follow in their train.

The emphasis placed on the study of the vernaculars at Achimota brings to our attention one of the greatest and most difficult problems in African education—that presented by the multiplicity of African languages. There is no linguistic problem in the world comparable to that of Africa. The total number of different languages exceeds five hundred; portions of the Bible have already been printed in nearly half that number. There is widespread agreement that on educational grounds the early stages of education should be in the mother tongue; the words in which a child has learned to name the things that make up his little world are the words which alone can have a real meaning for him. On the other hand, it is manifestly impossible to produce a school literature, still less a literature for general reading, in hundreds of African vernaculars. It is clearly desirable, where this can be done, to develop some *lingua franca* of African origin, or some one vernacular among a group of related languages, and to use it as the literary and school language for as wide an area as possible. The whole subject, which is obviously of the first educational importance, is receiving the careful attention of the Advisory Committee at the Colonial Office. A provisional statement has been submitted to the colonial governments and to educational experts for the purpose of ascertaining their views. The results of this representative and weighty expression of competent opinion will no doubt be incorporated in a revised memorandum which should afford valuable guidance in a very difficult question.

Happily there has been brought into existence within the past year to aid in the solution of the linguistic problem of Africa and in the better understanding of African mentality and institutions, the International Institute of African Languages and Cultures. It has succeeded in enlisting the hearty co-operation of all the principal learned bodies interested in African studies in this country, in France, Belgium, Germany, Scandinavia, South Africa and the United States, and of the missionary societies, Roman Catholic and Protestant. If it succeeds in carrying out the programme which it has taken in hand, it will make a most important and welcome contribution to that understanding of

Africa and the African peoples which is the indispensable foundation both of successful administration and of sound education.

A few words may be said in conclusion regarding the central and most formidable problem with which African education has to deal. Mr. Arthur Mayhew begins his recent brilliant review of the results of western education in India with the following pungent paragraph :—

“ It is only the professional who is perplexed by educational problems. Laymen, who are compelled as parents, politicians, or members of committees to consider educational aims and methods find nothing puzzling except the schoolmaster's inability to face obvious facts and apply unassailable principles. In India there has been no subject on which Viceroy and Governors have expressed their views with more ease and eloquence. Mind and pen move along well-worn grooves. The experienced Secretary, after spending his morning energy on financial and judicial files, drafts with the sinking sun his educational resolution, in which educationalists are reminded that their task is the formation of character and the training of good and productive citizens, and that their methods must be effective within the limits prescribed by economy and public opinion.”

The layman, while he is often profoundly ignorant of the complexities and difficulties of the task, is guided by a true instinct in holding that the formation of character is the primary purpose of education. It is human nature that presents education with its ultimate problems ; what to make of human nature and how to make of it what is desired are the fundamental questions to which an answer has to be found. These questions, everywhere difficult, are made still more difficult in Africa by the fact of rapid change. Sir Michael Sadler, in his recent little book on *Our Public Elementary Schools*, in which he includes a chapter on African education and its lessons, reminds us how large, though often unnoticed, a part is played in the formation of character by custom, habit and social tradition. Where a social tradition is firm and effective, no great harm is done if the schools confine themselves in the main to teaching the distinctively school subjects. The influences which touch the deeper springs of character are supplied in other ways. Religion, tradition, the home, prevailing custom and the institutions of the national life, all exert their influence on mind and heart. It is far otherwise when social tradition is in a process of dissolution. It then becomes imperative that the school should assume wider functions and definitely set itself to the task of creating and fostering the sense of social obligation and loyalty to the community.

This is the situation with which educators are confronted in Africa. A new and powerful civilisation is invading the life of peoples in a backward stage of development, and native societies are in consequence tending to disintegrate. The discipline of fixed social habit is rapidly breaking down. The old sanctions are losing their authority and force. The strength of traditional loyalties is being sapped. Deprived of his accustomed supports, the individual is exposed to new and fierce temptations. He finds himself in unfamiliar and perplexing situations, for dealing with which tradition, custom and past experience afford

no adequate guidance. In circumstances such as these it becomes necessary to address ourselves, in Sir Michael Sadler's words, to "the hazardous and difficult task of endeavouring to replace by means of a wise and spiritual education the constraint of custom by the nobler constraint of conscience." How is this to be accomplished?

The first step, as the memorandum of the Advisory Committee points out, is to find ways "to improve what is sound in indigenous tradition. This task of conserving and developing the valuable elements in traditional loyalties, beliefs, customs and sanctions, demands a thorough study of the native mind and of native institutions. It may be hoped that a fresh stimulus will be given to such study by the new International Institute of African Languages and Cultures. But when the utmost has been done to conserve what is good in indigenous traditions, the old supports will be found insufficient to bear the strain of the new conditions. Whatever a wise education may be able to do to make the transition easier, the old simple beliefs and the existing social fabric must in the end give way under the impact of modern means of communication, modern industry and modern social and political conceptions.

Much may be accomplished in the second place, by an education closely and systematically related to the real interests and needs of the community and progressively adapted to the changes in its life, such as has been outlined in the earlier part of the paper.

But there still remains the problem of finding a substitute for beliefs and sanctions which have ceased to be a restraining force, of influencing the deeper springs of character and of inculcating allegiance to a spiritual ideal. This brings us face to face with questions which lie outside the scope of this paper. The fundamental difficulty lies in the fact that western civilisation is at the present day without any generally or even widely accepted philosophy regarding the ultimate meaning and purpose of life.

Nevertheless, governments in Africa, confronted with a problem the gravity of which is only too apparent, are in remarkable agreement as to the need for the aid of religion in meeting the difficulties it presents. The Advisory Committee lay down in their memorandum that "the greatest importance must be attached to religious teaching and moral instruction," and recommend that both in schools and in training colleges they should be accorded an equal standing with secular subjects." In the Union of South Africa every recent Commission which has dealt with native affairs has urged that native education should be on a religious basis. The Belgian Government, in its recently issued policy for native education, is equally emphatic on the subject.

The difficulties in the way of government itself undertaking to give religious instruction, while at the same time maintaining, as it must, a fair and impartial attitude towards different religious beliefs, are obvious. The simpler conditions of Africa have, however, permitted a greater freedom of experiment than has ever been possible in India. In certain Muhammadan areas provision has been

made for the teaching of Muhammadanism in government schools. Where the people are predominantly Christian or pagan, experiments are being made in giving Christian teaching with, of course, adequate provision for the exemption of those who do not wish to receive it. But the educational services of governments are open to men of all religious beliefs, or of none, and there are inevitable limitations in the adoption by governments of any general policy that includes religious teaching. If religion is to make a contribution to a successful solution of the educational problem in Africa, it will have to be made largely through the efforts of Christian missions. For this, as well as for other reasons, it is the declared policy of His Majesty's Government, of the Government of the Union of South Africa and of the Belgian Government, to welcome the co-operation of missions in the carrying out of the educational task.

The partnership of government and missions in education—which has existed in India since the famous educational despatch of 1854, has long prevailed in the Union of South Africa, and is now the accepted policy in the British Crown Colonies, Protectorates and mandated areas—has made in Africa an auspicious beginning. While mistrust on both sides has not been entirely overcome the partnership thus far is working with remarkable success. Much will depend in the long run on the real educational aims of both sides. If the aim of governments is not primarily to produce clerks or artisans, but to educate *persons* and if missions, on the other hand, are not content with making converts, but set themselves with breadth of view and educational understanding to the task of trying to make *men*, there should be a large field within which close and effective co-operation should be possible.

Regarded from the standpoint of an ultimate philosophy of education the arrangement is a compromise. But compromise is not uncongenial to the British temperament. And it may be permitted to some of us to cherish the hope that out of mutual respect and practical fellow-working something greater may grow; and that, as the years pass, religion, freeing itself from the shackles of intellectual timidity and intellectual narrowness, and gladly availing itself of all the help that modern knowledge can give, while abating nothing of its enthusiasm and devotion in the service of God and humanity, and science, surrendering—as in the person of some of its most distinguished representatives it is to-day surrendering—the claim to be the sole avenue to a knowledge of reality, and at the same time consecrating itself increasingly to the service of social purposes, may be able more and more closely to unite their forces in the task of creating a new, contented and progressive Africa, capable of making its own distinctive contribution to the life of humanity as a whole.

DISCUSSION

THE CHAIRMAN said the audience had had the privilege of listening to a paper which, he believed, in future would be regarded as the best short statement of the present hopes and fears in regard to education in tropical Africa. Very great

knowledge and thought had gone to the making of the paper, and he congratulated the author on having brought within a small compass a well proportioned account of an extremely complicated and urgent situation. He had had the opportunity a few days ago of reading the impressions of an American professor who spent the better part of the year in visiting the various parts of Africa, east, south and west. The letter he received was private, but there were three passages at the end in which the observer recorded the deepest convictions resulting from the journey, and he should like to read them because they illustrated the paper that had been read that evening. The writer referred to the amazing capacity for education and progress of African peoples, and said: "Let no one who wishes to find proof of the permanent inferiority of coloured races go to Africa, for he won't find what he seeks. The progress already made here by the masses of the country in the few years they have been in contact with European civilisation refutes this claim, to say nothing of the outstanding accomplishments of exceptional individuals who with equal training and opportunity are holding their own with men and women of culture and learning of other races." With regard to the need for and efficiency of missions and missionary education the writer said: "Like many an American educationist, I have always felt, if the truth may be honestly confessed, that missions were a good thing in their day but that they were always a bit sentimental and emotional and not to be compared with hard-headed Government effort for the support of schools along systematised, tax-supported lines. This attitude I am now frank to admit has been drastically modified. The day for missions, I have learned from this tour, is still with us and will be still with us for a long time to come. Moreover, they are for the most part remarkably efficient and successful agencies, considering their many handicaps, even when measured by the exacting standards of modern education, and they contribute at all times a spirit of devotion, self-sacrifice and character which is seriously needed at the present juncture in world affairs." . . . "The third point which has impressed me most is the justice, efficiency and humanity of Great Britain as a colonising agent. In this respect she unquestionably surpasses all other nations. This is not saying that she has not made many mistakes in the past or is not perpetuating some in the present, but rather that her conception of the responsibility of the leading nations for primitive and backward peoples, as worked out under the mandate system, and of the principle of trusteeship, is the highest and most advanced conception of this difficult task which has been adopted by any country. And this from one of Irish ancestry whose childhood was coloured by grandfatherly tales of the year '98, when the troubles were great, and who started this trip with a pretty considerable bag of reservations." Those who lived and worked at home wished on occasions like the present to pay their respectful and heartfelt tribute to the great work which was being done by British public servants and missionaries and doctors, both men and women. He might say as a colleague of the author's on the Committee he had mentioned how great a thing it had been for Great Britain that Sir Frederick Lugard wrote his book, "The Dual Mandate." In European politics at Geneva he was not only one of the great forces of the time, but one who had showed in his life and speech what the ideals of British administration were. He himself should feel bitterly opposed to all the new and promising plans for the improvement of education in tropical Africa if he thought they were designed or that they would result in curtailing the intellectual opportunities of the African races. He believed exactly the reverse to be the case. During the last 20 or 30 years those who had lived in countries in the west where modern education had reached its highest stage of present development, had begun to see the problem of education in Africa in exactly the same way and in the new light. They realised that where education had been most

successful it had drawn much of its power from a social background of law, beliefs, traditional wisdom, habits and judgment, the cult of thought and control of character. There must be an individualist side to education, one of the greatest of its sides, because education took its pupils one by one, and one of its chief purposes was to stimulate by equipping the powerful, fresh-minded individual to break new paths. But behind the individual, and woven into the scheme of education, there was always the texture of social community life, and that influence had been strongest where there had been the most forward looking self-respect on the part of the community itself. Therefore, gradually in the west people were beginning to think of the school not as an isolated institution but as something which would be partly the focus of a number of agencies and partly itself a sharer with other agencies in the work of social betterment. It was because they believed that the future of education lay with that view, because they believed that education seen in that light was going to be most wisely developed, and because they were convinced that it would do more for Africa than any other view, that they rejoiced that the new British policy in regard to education in tropical Africa was affected by that outlook. But the more the question was studied the more it was realised that it was necessary to get every hour closer to the facts and that every generalisation, even generalisations about the value of the vernacular in the training of the mind, needed to be constantly brought into contact with the realities of African life. Therefore he greatly welcomed that evening from the field many who could speak with fresh and deep knowledge of the problems, and in inviting them to take part in the discussion he would venture to ask one or more of them to touch firstly on the problem of whether it was possible to look forward to securing, for the service of tropical Africa in the new mission of education, men and women of the calibre and power that were needed for leadership in the great opportunity now presenting itself. He believed it was possible and that their influence was doing much already to attract to the field of work men and women from Great Britain who could take a very noble part at a very critical juncture in the world's affairs. Secondly, would it be possible, and in what parts of tropical Africa, to use women as agents in the general plan of primary education? Women in the West were nearly three-fourths of the teaching staff, and it might be possible to draw upon that source of supply in Africa for the teaching staff. Thirdly, what did experience show as to the course of training which those who went into the educational service in tropical Africa should undergo, and what course of training under the circumstances was really possible and most effective in fitting the future teachers for work in schools in every grade of education? And lastly, was it possible to hope, as he trusted it was, that the resources of African Governments would enable them to furnish the other agencies, non-governmentally engaged in education, with that measure of financial help without which it would appear to be impossible under modern conditions to give the kind of education which the author and Dr. Jesse Jones had both so eloquently described? Education must not be starved at the very moment when it was necessary to give it in its fullest and its best form.

THE REV. E. W. SMITH (British and Foreign Bible Society) said he was hardly prepared to discuss the four points put forward by the Chairman, but he wished to say that he was a whole-hearted supporter of that new education of which Dr. Jesse Jones and the author and the Chairman were such eloquent exponents. He was a supporter of the new education because of the experience he had had of the old education. He began teaching the Africans nearly 40 years ago, when he was quite young, and later on he had experience as a teacher in two of the institutions in

South Africa where young Africans were being trained for the teaching profession. They came to the institutions very imperfectly instructed in English, and the teachers in the schools were compelled by the Cape Government to carry on their training in English, using English text books, and preparing students for the same examinations as taken by English candidates. Nothing in the schools had the slightest relation to the past life and culture of Africans, or to the community life of Africans. The subjects taught, or supposed to be taught, related entirely to English or European matters. He spent more time than he should like to say in teaching the names and genealogy of the early Saxon kings of England ! The young men were given no teaching about the cultural elements of their own people, but every one of them could have told quite accurately the names of the peninsulas, islands and capes of Great Britain. Anything that related to their past life was a heresy even to mention. The use of their language was banned. Any young man who spoke his own mother tongue was punished. That was the old education. It could be called education, but he himself did not like to give it that name. Even in religion every bit of scriptural instruction, hymn singing and prayers was in a language foreign to the students. The effect was absolutely disastrous. On the first journey from Cape Colony to Basutoland he travelled in a post cart with a Government Magistrate, and there were two Africans in the cart, one of whom was mad, and the Magistrate said it was a case of "much learning." Under the dreadful cramming system some of his own pupils had gone out of their minds. The worst point of the old system was that the students who came to them at tremendous sacrifices were given a totally wrong idea of what education was, and consequently one of the greatest difficulties in Africa to-day, wherever that old system had prevailed, was that the natives thought that what used to be given them was education and what was now proposed to be given to them was something less than education. He did not believe that the new education would in the slightest degree set a lower standard than European education ; it would set a higher standard, but the Africans had to be persuaded that that was so. Recently he had noticed in a West African newspaper, printed in English, a comment on the memorandum on the language question sent out by the Advisory Committee which said, "We tell the Colonial Office Committee frankly that we do not want any of their fads ; let them get on with business." This was in reference to a proposal to introduce the African tongue into the schools. The tendency of the old education had been to give the people an idea that there was nothing of any value in all their past culture and this was a very grave blunder. It was possible to picture the difference between the old education and the new as follows. The old education said : "Here is a Waterloo Bridge that is condemned ; it is useless ; let us do away with it ; let us root out the very stones of the foundations, and then let us build up something entirely new out of the concrete and steel that we import from another country." But the new education says : "Here is an organism, a tree—it may not have the best fruits upon it, but its roots go down deep into mother earth ; let us see what we can do with it ; we will dig about it, fertilise the soil, prune the roots and branches and graft here and there as we think best, and do the best for that tree in the expectation that it will bring forth good fruit." It was because he believed so thoroughly in the capabilities and educability of the African that he was such a whole-hearted supporter of the new education. In studying the reports of the Phelps-Stokes Committee and many other documents issued on the subject of African education, he always noticed that none of them had remarked, or not to the degree they ought to have done, that the Africans themselves had their own system of education : it was an astonishing thing that that should not have been noticed, but he supposed it was because the Africans had no books or

blackboards. They had a very valuable educational system of their own, how valuable might be gathered from the simple fact that when Baden Powell wished to found his great movement—a movement which he personally regarded as the greatest of modern educational movements—he went to Africa and to the tribal customs of Africans to get the chief principles, which meant that after all there was something to be learned from Africans. In the native method of education, and especially in their initiation ceremonies, there was a real educational principle, and the remarkable thing was that Dr. Jesse Jones and the author and even ultra-modern educationalists had simply gone back unconsciously largely to the principle adopted by the Africans, that education should be for life, and should make for the well-being of the community. It might happen that by way of Africa there might come even to this country some educational reform.

MAJOR A. G. CHURCH, D.S.O., M.C. (Colonial Office Advisory Committee on Native Education in Tropical Africa) said that the lecturer's remarkable study of African education was one which must have filled many of those present with a very considerable measure of admiration. There were one or two points which he should like to dwell upon. The author had rightly laid stress on the importance of health as a factor of education, and had pointed out that the educational service could contribute largely to the improvement of the health of the population of Africa, particularly East Africa, where people were in closer contact with the Whites than on the other side. Too much might be hoped from the health service by way of western education; it was not altogether the improvement of a few of the natives that was going to arrest the rapid decline in the native population. It seemed to him that much of the trouble was due to the destruction of tribal ceremonies, arts, crafts and industries. Where these had been destroyed the interest of the natives in their own surroundings was also destroyed. Dr. Jesse Jones had laid stress on the necessity for the educational service to be tuned to the environment, so that the native could value and appreciate his own language and thought and his own music, and feel a certain amount of joy in what was his, and not lean everlastingly on the new and the novel. The investigation of Pitt-Rivers in Melanesia had thrown some light on the importance of arousing a real interest in the native customs and habits and arts and crafts, if the native population was to persist. The Advisory Committee had rightly laid stress on the importance of building up an entirely African educational system, while not depriving the Africans of the best in European education or the opportunity of learning the English language, because the greatest gift that could be given to the Africans was the gift of the English language, and the greater the number of people who knew that language the better it would be for them. The Committee had stressed the point that they desired African universities and an African educational system which was not based on the examination system of the universities of Great Britain. The external examination system of London and Durham had gone to the most absurd lengths turning out so many African graduates. If Africans wanted a university education they should have it in Africa. The external examination system should be abolished in so far as it affected the African people, because no one in this country could see how it could be of any value to them in Africa. That was, he believed, the view expressed in various ways by the Advisory Committee. They wanted to build up African institutions, they wanted an African university in the west and another in the east. He suggested that the best position for the eastern university would be the centre of the mandated territory of Tanganyika.

SIR HERBERT J. STANLEY, K.C.M.G. (Governor of Northern Rhodesia) said he could not claim to speak with any authority on the subject of education, but he had had something to do with the administrative side of it in the last few years. Very soon after he assumed the Governorship of Northern Rhodesia it was his privilege to entertain Dr. Jesse Jones, with whom he had some very interesting conversations, and on the advice which Dr. Jones gave to him and his fellow workers they evolved a scheme for starting a system of native education in Northern Rhodesia in a small way, but on foundations which they hoped would be capable of bearing a very much larger super-structure. The scheme was submitted to the Advisory Committee in London and a start had been made with it. The financial resources were very exiguous, and it was necessary to proceed with reasonable caution. It was to some extent a new departure in Northern Rhodesia. The State up to then had taken no direct part in native education; what had been provided outside the Barotse District had been provided entirely by missions, and he wished to pay his utmost tribute to the missions for their work. It was decided that the Government should work in the first instance entirely with and through the missions. The system was to offer subsidies or grants to missionary societies, who would undertake to do certain things. It was not so much that they wanted them to teach the three R's—that they would do without Government support—but they wished them to teach things which their resources would not permit them to teach without some assistance from the Government, such subjects as hygiene, agriculture, and the practical side of education, as distinct from the purely literary side. They also wished to help them to provide a better training to and a better supervision over the native teachers in the village schools. It was to the village schools that they had to look in the first instance. It could not be expected that throughout the territory any considerable number of natives could be found capable of benefiting from a higher education unless a beginning were made by training the natives in the villages, and by giving a fairly widespread elementary education to all that could be reached. It was considered that eventually upon that elementary teaching something higher would be built up. He did not know whether the system was proving a success, because it was only about two years old, but it was successful in the one respect that it had received the unqualified support of all the various missionary bodies, who were co-operating with the Government in the most cordial and friendly manner to an extent which was not surpassed in any other territory in Africa. A conference was held at which there were representatives of the most diverse Christian creeds, and it was satisfactory to find that they concentrated, not on the differences which divided them, but upon the task which they were called to consider, and they all worked together to devise a useful curriculum and to help the Government to draft useful conditions which might attach to the grants, so that the maximum benefit might be given to the natives. One of the purposes for which he was returning to Northern Rhodesia was to open a Missionary Conference at Livingstone in July. With regard to the Chairman's question as to whether the Governments felt confident that men of the right stamp would come forward to undertake the work of education, he had no doubt that they would do so, because he thought the importance and interest of the work would attract them, and he had no doubt that the Governments would do everything to attract the right men and make them happy and comfortable in their work. With regard to women taking a larger part in educational work in Africa, he thought there was scope for European women to do a great deal more than had been done in the past, although they could not be placed in all parts of the country. Much of the elementary education of the African would have to be carried on by Africans themselves, because no Government could afford an enormous staff of European teachers in the village schools. He did not think the

native woman was fit to undertake educational work at present, because she had not advanced sufficiently to be entrusted with educational functions, although he saw no reason why she should not so advance, and one of the principles of the scheme in Northern Rhodesia was an effort to do something for the education of native women. There was no reason why eventually she should not take her share in the education of the young. With regard to the question of the Governments being prepared to provide the funds which would be needed if the missions were to be helped to carry on their work, in Northern Rhodesia they were doing what they could, but their resources were limited, and it was necessary to consider in an increasing measure not only the wishes of people at home, but the wishes of the settlers and the Europeans in the territories. At present Northern Rhodesia and Kenya, he thought, were favourably disposed to the education of the native, and if they did not go too fast, and did not antagonise the Europeans, he believed the latter would be willing to co-operate and would not hamper the Government. Those who were concerned with the practical carrying out of the policies started in London felt indebted to people like the Chairman and the author for helpful advice and for their interest in what was being done.

MAJOR H. VISCHER (Secretary, Colonial Office Advisory Committee on Native Education in Tropical Africa, and International Institute of African Languages and Cultures), said the keenness for education on the part of natives was perhaps best illustrated by the figures. In 1921 the total amount spent in the West African dependencies, Sierre Leone, Gambia, Nigeria, the Gold Coast, etc., was £250,000, and 150 Europeans were employed in various educational departments. In 1926 the total amount was £650,000, and the Europeans employed numbered over 300. It was extraordinary what an interest the natives themselves took in education; they not only wanted their children to learn English and to obtain employment under Government, but they were beginning to look to the school put up by the Europeans to replace the tribal training and the initiation ceremonies and the tribal discipline, which necessarily had suffered from the economic development of the country. A good many of the native schools were under the direct patronage of the native chief, and the Council of Elders assisted the directors of education in the management of the schools. With regard to the lecturer's reference to the importance of giving something which would replace the tribal sanctions and traditions which were being destroyed at the present day, he could best illustrate the need for that by an experience of a friend of his who told him that when he was in the Congo he visited a village not far from the railway, in the centre of which stood the chief's house. The house was unoccupied, but the door was left open, and in front of the door a branch of palm tree was stuck in the ground, which meant that the Chief was away and therefore no one must touch any property in the house. A little further on was another village which was under European influence, and there too the chief was away, but there was no palm tree in front of the door, which was securely fastened by a European padlock. The problem that had to be faced in Africa was a very difficult one, because he did not believe that any native, whose tribal organisation had been destroyed and whose traditions and sanctions had been ridiculed by European influence, would ever go back again to those traditions and sanctions. Something had to be given to him to replace the tribal discipline and the tribal code of morals on which it was based. We could only give him what we had ourselves, but we must give him the best. He would like to inform those present that the Conference called by the Secretary of State at the Colonial Office in 1923 was really called in response to a letter received from a Missionary Conference for

which Mr. Oldham was responsible, pointing out the present needs of African education, and asking for the appointment of such a body as the Advisory Committee. The International Institute of African Languages and Cultures, to which people might look for a great deal of help in their work, was also brought into existence at a Missionary Conference held under the presidency of the lecturer.

MR. S. M. GRIER (Director of Education, Southern Nigeria), said the subject of the paper had interested him very much, but he did not feel competent to say anything at the present time. His connection with education had been an exceedingly short one, and the fifteen months he had been Director of Education in the Southern Province had convinced him how extremely little he knew about such a very difficult subject.

MR. JAMES A. ROSS (Northern Rhodesia) said that when Sir Herbert Stanley came to the Province he had the privilege of becoming very well acquainted with him and found him very sincere in his desire to promote the religious and educational training of the natives. He should like to ask whether the Conference of Missionary Societies laid sufficient stress on the tremendous impact of the Western industrial system now being introduced into Africa, and the fact that hundreds of thousands of the African people were being employed away from their homes for long periods, during which they were exposed to a number of temptations. It was a remarkable thing that the worst of the Western social system was imported into industrial centres in many parts of Africa, and vice, which was spoken of with bated breath at one time, was perfectly common now. The work he had been endeavouring to carry out in the last few years had been to make the tribes self-supporting economically at home, and keeping out of industrial centres every native that he possibly could. Great stress was laid upon the improvement of their homes, and upon hygiene. There were a great many industries which might be introduced into the villages, and he was looking forward to going back to carry on the work. The Government would help as far as possible. He realised that the development of Rhodesia would go along the lines of the exploitation of mineral wealth, and it seemed to him that a great deal could be done to ameliorate the conditions prevailing in the industrial centres, and he was wondering whether a Conference of Missionary Societies might not pay some attention to the question as to whether they could not make efforts for the well-being of the natives in industrial centres. He thought that might be productive of great good. Sir Frederick Lugard had put his finger on one of the crucial questions when he said that the building up of model settlements near industrial centres might cope with the evils that existed.

SIR. HUMPHREY LEGGETT, R.E., D.S.O. (Chairman, Dominions and Colonies Section) said he had the great privilege on behalf of the Society of proposing a vote of thanks to the Chairman and also to the lecturer for having given such a remarkable exposition of perhaps one of the greatest problems and also one of the greatest opportunities that any imperial nation had ever had. He was able to bring a message from Sir Frederick Lugard, who deeply regretted that ill-health prevented him from being present. Sir Frederick asked him to say that after reading the paper he should like to express his thanks for the work Mr. Oldham had done, and the manner in which he had summed up the great problem. The Royal Society of Arts had been discussing educational questions for 150 years, and only three or four years ago the Society had the privilege of offering the greatest reward in its gift, the Albert Medal, to two great medical men, Sir David Bruce and Sir

Ronald Ross, of whom it was said in one of the speeches on that occasion that by their great discoveries they had added a new continent to the world. By their discoveries in regard to sleeping sickness and malaria they had done much to improve the hygiene of the African races, and by giving to the Africans the British Pharmacopœia and the Pax Britannica they were giving opportunities for the African races to grow as the other great races of the world had grown. It was not much good adding millions of people to the world unless it was known what course they were going to take. The problem was largely one of health, security and education, and he was not sure that it would not be more appropriate if the Department of Education were known in the future as the Department of Education and Welfare, because the two were intimately connected. Sir Frederick Lugard having pointed the goal to those connected with Africa, the next step was that the people of Great Britain should be led as widely as possible to understand the importance and responsibility of their imperial destiny in connection with African work. The Royal Society of Arts tried to play its part by affording a forum for discussion, and he felt sure it had never had a more important subject discussed than that which had been before the meeting that evening or a more eloquent exposition than had been given by the Lecturer and the Chairman.

MR. C. W. HOBLEY (Late Senior Commissioner, Kenya), in seconding the motion, said the Council of the Society was to be congratulated on its foresight in having such a discussion. He had been working in Africa for many years, and welcomed the new thought that had come into being during the last few years. The whole question boiled down to the fact that co-operation must be more than a pious wish, and must be brought into effect in Africa. In practice co-operation was a very difficult matter, because each department ran its own show separately, but the whole secret of success was continuous co-operation between the District Officer, the other Government departments and the Missionaries. To develop a civic spirit in the tribal units was a matter of the most vital importance and the possibility of achieving this lay chiefly in the hands of the District Officer.

The vote of thanks to the Chairman and the Lecturer was then carried unanimously.

MR. J. H. OLDHAM said he wished to express his thanks for the very kind things that had been said about the paper. It was a great honour to be allowed to introduce a subject of such importance, an honour greater than he deserved. He was also grateful to the Chairman for presiding. It was very encouraging that such a company as had met that evening should gather together in London to consider the most important question of the education of the Africans.

NOTES ON BOOKS.

THE RT. HON. SIR MORTIMER DURAND, P.C., G.C.M.G., K.C.S.I., K.C.I.E. : a Biography by Brigadier-General Sir Percy Sykes, K.C.I.E., C.B., C.M.G. London : Cassell and Co., Ltd. 25s. net.

Call no man happy until he is dead. This biography strongly points this moral. If ever there was a fortunate man, Mortimer Durand was he ; at least so it seemed. After a rather unusual education—three years with a Swiss pastor near Lausanne, four years at a preparatory school in Norfolk, four years at Blackheath Proprietary School, and four years with a crammer—he passed the Indian Civil Service Examina-

tion in 1870 at the age of 20. The child is the father of the man, and this training in small private schools probably increased the shyness and diffidence in general society which lasted throughout his life. In view of his parentage, one can hardly call it *morgue Britannique*, but it was very akin to it.

He did not take a high place at the open competition and so went to Lower Bengal; but he passed out after the two years' training higher up on the list. Still his luck began by his going to Calcutta in March, 1873. His father, Sir Henry Durand, had played a distinguished part in India. In 1840, as a young sapper officer, he fired the mine that blew in the Kabul Gate of Ghazni. The fall of that city led to the flight of Dost Muhammad Khan, and Kabul and most of Afghanistan fell into the hands of our nominee, Shah Shuja, whom we were restoring to his throne. Fortunately for himself, Henry Durand left Kabul before the catastrophe occurred in the winter of 1841-42. His gallantry at Ghazni attracted attention and he became Private Secretary to the Governor-General, Lord Ellenborough. Then he went into civil and political employ, save for a short term of active service during the second Sikh War in 1848. He was Political Agent at Bhopal, where Mortimer Durand was born, Agent to the Governor-General in Central India during the Mutiny, and after a term of service at the India Office he became Foreign Secretary and eventually Lieutenant-Governor of the Punjab. There his fortune failed him, and soon after taking over charge, while entering the small town of Tauk at the mouth of the Gumal Pass on the north-west frontier through an arched doorway, which was too low for the elephant which he was riding, he was crushed against the arch and killed in January, 1871.

In India family ties are strong. His father's brilliant career and tragic end were the best of introductions for him at Calcutta, where his father's old friends were at the top of the tree. Sir Charles Aitchison, who followed Sir Henry Durand as Foreign Secretary, took a special interest in him, and before he had two years' service he found himself an attaché in the Simla Foreign Office. Then he married a charming wife, but the very fascination of his domestic life, coupled with the work in the Foreign Office and his literary tastes, which showed themselves as early as 1879, led him to draw more and more into his shell, and prevented his enjoying that wide-spread popularity to which his splendid physical and mental qualifications clearly entitled him. How he managed to do as much literary work as he did in India was always a wonder to his contemporaries. He passed definitely into the Political Service, and after a short term of service in Rajputana went up with Sir F. Roberts to Kabul during the second phase of the second Afghan War in 1879-80. The biography shows that even Lord Roberts was not entirely above the feeling of jealousy which is often felt for political officers, and Durand apparently sometimes had difficulty in getting his views fully considered. There was a story of a distinguished general who declared that if his Political Officer tried to interfere he would place him under arrest. Yet it was information collected by that Political Officer through civil officers and communicated to the Chief of the Staff which enabled the general to alter his plan of campaign and attack a pass not fully manned by the enemy successfully instead of perhaps reproducing the disasters of the Ambela Pass. The functions of the General and his Political Officer are quite distinct and they ought not to clash, but, alas, they sometimes do. With the warning of the 1841-42 catastrophe before them, it is extraordinary how nearly the disaster was repeated. The force was shut up again in Sherpur and things looked badly, but, fortunately, this time we had a superiority in armaments and were not handicapped by Elphinstones, Sheltons, Macnaghtens and Burnes, and the jealousy between British and Indian Service officers was greatly

reduced. Durand came out of the war like his father with a high reputation, and his advancement was rapid. He became Under Secretary in 1880 and was appointed Foreign Secretary by Lord Dufferin in 1885 when only 35. He was tall and of a heavy build and had to keep himself fit by riding and football. Several excellent political officers first attracted the attention of the Head of the Service by their skill at the game. He did not, however, encourage candidates who went in rather for cricket, as this involved too long absences from office. His personal work must be sought rather in the despatches than in the notes on the cases, which, happily for him, had not in his time attained their subsequent voluminous developments.

He deserves great credit for working out the idea of forming Imperial Service Troops out of the Armies of the Indian States, and these troops not only gave an opportunity to the chiefs and leading men of the States to receive a military training and see service, but also rendered valuable services in much frontier fighting and during the Great War. Now they have been given up, as the Chiefs preferred to have all the forces they wished to retain trained to the standard of Imperial Service Troops under general British supervision, but it was Durand's scheme which paved the way for this reform, which improved the military position in India. As Foreign Secretary he had a much freer hand than was the fortune of his successors, and he could travel about widely and make up for his want of general administrative experience by seeing things on the spot, but it would perhaps have been better for him if his career had not been so meteoric and he had acquired more general experience of administration. Still his work in the Foreign Office was highly appreciated by two masters of diplomacy like Lords Dufferin and Lansdowne, and the crown of it was his mission to Kabul to the Amir Abdul Rahman in 1893 and the delineation on the map of the boundary of jurisdiction between India and Afghanistan. This Durand line is still, however, one of the standing problems of Indian frontier policy, and the pendulum sways between the forwards who urge an open border and occupation up to the line, and the backwards who depreciate any interference beyond an administrative boundary which lies well to the east of the line. There is, and can be, no definite rule in such matters, and action must depend on the conditions of each part of the border and practical politics. There was much to be said for the Indus as a boundary. With railways on the east bank and gunboats on the river, it could undoubtedly have been made a very perfect administrative border in ordinary times and one which could have saved us much trouble and expense. But it would not have secured us against the risk of the trans-Indus countries being dominated by an aggressive military power, and our river line held by troops softened by the ease of purely internal service in India would probably not have stood the strain of an invasion from the west any longer than did the former attempts to hold the Indus against western invaders from Alexander onwards. It was this danger that took us across the Indus and brought us up to the foot of the hills, a position which, with active and brave raiders, egged on and even supported from the rear, is almost hopeless. The Durand line was an attempt to rectify this and to settle our liabilities vis-à-vis the Afghans. It was a most difficult task to fix a line which the Amir would accept and which would meet our views, especially as we had no proper maps and were ignorant of actual conditions beyond our administrative border owing to the close border system. It is surprising that the Durand line worked as well as it has done. Where it failed was when a tribe was divided up, as in the case of the Wazirs and still worse of the Mohmands. In the latter instance Durand perhaps was not as clear as he might have been. The Amir said when the rough

map was produced: "This gives me the Mohmands." As a matter of fact the tribe was divided. Durand is believed to have said: "the map is on a small scale and imperfect; you will understand it better on the large scale map when ready." The Amir and his son Habibullah later did understand it, and the Durand Line has never been demarcated in the Mohmand country. This indeterminate condition has led to three serious Mohmand attacks, in 1897, 1908 and 1919. The whole trouble here arose from the policy of reckless scuttle adopted in 1880, when the Liberal Government came in. Under the treaty of Gandamak the Mohmands had come under the British Government. The Lieut.-Governor of the Punjab, Sir Robert Egerton, received and recognised Sadik Khan, the new Mohmand Khan of Lalpura and his brother, Muhammad Hassan, in a durbar at Dhakka on 19th March, 1880. If only the whole treaty had not been upset, the Mohmands would probably have settled down quietly, as their country is fairly open and they are industrious cultivators and own and cultivate large areas on the canals in Peshawar. As so often happens, this unfortunate mistake cost many lives and much money both in the Mohmand country and in the Khaibar tract, where road after road and two railways have been built at much expense to correct the error, and still we are without an adequate railhead at Dhakka. The Amir, when approached on the subject of the demarcation of the Line, always said: "Certainly you send up your commissioners and mine will meet them, but as you say these sections of the Mohmands are yours, I cannot give your Commissioner an escort or guarantee his safety." When the Mohmands made their unprovoked attack in 1908 and our troops had to enter their country, Lord Morley was nearly induced to agree to a commissioner being sent up and the Amir requested to send his man forthwith. But at the last he would not violate the principles of a lifetime, even though they seemed to be wrong, and the game of intrigue went merrily on. This tale illustrates the difficulties in practice of the Durand Line. There were also frequent difficulties with the Amir about the tribes on our side of the Line. When they gave trouble, and it was believed he was not discouraging this and could stop it, his reply was, "You say they are your subjects, so they are no concern of mine and you can punish them yourselves." But taking it all in all, it was a good piece of work, and enabled the geographers to show the Indian border definitely on their maps.

How little the Afghans know or care about maps is clear from the fact that in 1905, Amir Habibullah Khan, in dealing with his scheme for allowing us to make a railway along the Helmand to Seistan with a cantonment, he was working on the original boundary map made out by Durand, which showed the line close up to the river and not on the amended map prepared by Sir Henry MacMahon which gave the Afghans a large tract of desert to the south!

Durand's reward was the post of Minister at Tehran, for which he had many qualifications, but one defect, in that he did not belong to the Diplomatic Service, and close services resent the intrusion of outsiders, just as the old East India Company's servants resented the introduction by Lord Ellenborough of Durand and other military officers to civil posts. In Persia he was able to continue his boundary work by arranging the demarcation of the frontier between Persia and Mekran, and he well maintained British and Indian interests at Tehran. The Legation, however, was not, it is believed, a happy family, and Durand could not placate the jealousy of his somewhat difficult surroundings, though this was not perhaps his fault. The jealousies created by his appointment at Tehran followed him throughout, though they died down somewhat while he stayed in the quieter backwaters of Madrid, where his fine presence and stately manners pleased the

Spaniards. When he gained the supreme object of his ambition as Ambassador at Washington, fortune seemed to have no other favour left to give him. Detractors came to the front again. Mr. Roosevelt desired the appointment of a cheerier personality and a personal friend. Wires were pulled and an atmosphere of intrigue was created. How he was recalled is explained in the biography, and the undeserved slights involved undoubtedly broke his proud and somewhat pessimistic spirit. Like most Indian officers, he was a poor man and honest withal, and he could not keep pace with the millionaires of America. The Ambassador's salary of £7,500 was quite inadequate for the position, and this also prevented him from gaining a general popularity. After he left, the emolument was raised first to £10,000 for Bryce, and apparently subsequently to nearly double that amount for Sir Auckland Geddes. Still, with his reserved nature and his disdain of personal advertisement, he was hardly the man for Washington. After this set-back he was too proud to consider an Indian governorship, and it is not certain if he would have been well adapted for such in the altered conditions which were arising even in 1907, as he was not a very fluent speaker, or capable of rapid adjustments of ideas to meet political exigencies. He was probably wise to retire into private life and to content himself with the sympathy of his friends and with his literary work. He died in June, 1924, and will be long remembered as a brilliant and far-seeing officer and a great gentleman.

At any rate, Durand was most fortunate in his biographer. Sir Percy Sykes is one of our foremost authorities on the Near East, and began his political career in Persia under the auspices of Sir Mortimer, for whom he always felt a devoted admiration. The biography, apart from the interesting early reminiscences which are Durand's own work and the extracts from his letters and diaries, is skilfully woven on a framework of the complicated history of Persia and Afghanistan in the eighteenth and nineteenth centuries, so that the book has a great permanent value for all students of Near Eastern questions. It is, of course, full of Eastern names, yet there are but few misprints, such as Badish Khel for Balish Khel and Latabank for Lataband, and some slips as Afghans for Sikhs on p. 69, and south-eastern for north-eastern on p. 158. Parapamisus on p. 140 should be Paropamisus, and it was the Jodhpur Cavalry which led the Imperial Service Cavalry Brigade into Haifa. Fath Khan in Afghanistan and India is Fatheh Khan, and Firozapur on p. 74 should be Firozpur as it is the City of Victory and not the Turquoise Town. Ahmad Shah took the title of Durr-i-Durran or the Pearl of Pearls, but it was afterwards rather generally turned into Durr-i-Duran or the Pearl of the Age, but no doubt his descendants should be the Durrenis rather than the Duranis.

CARAVAN TRANSPORT ACROSS MONGOLIA.

The following data regarding caravan transport across Mongolia have been collated by the United States Department of Commerce, and published in the official *Commerce Reports* :—

The inadequacy of transportation facilities in China proper and the contiguous territory has long been a topic of discussion among those interested in Far Eastern trade methods. It would undoubtedly be desirable to have in China and its great desert reaches to the north a network of well-managed railways and numerous motor roads which would expedite the transfer of goods ; but should a railway ever be built across the Mongolian grasslands it would wipe out for ever the present

slow and ineffective but picturesque method of transportation by camel caravan. Anyone travelling in the neighbourhood of Suiyuan Province, and, particularly, in the city of Paotowchen, in the spring or autumn of the year, will see endless processions of camels, laden with merchandise for the farthest parts of Mongolia and Chinese Turkestan, swinging silently on towards the desert lands which lie between them and their destination.

Situated at the head of rail transportation on the Peking-Suiyuan railway, and on the Yellow River, which flows down from Lanchow (Kansu) for a distance of approximately 1,000 miles, Paotowchen is accessible both by rail and water, and has thus become an entrepôt for goods in transit from China proper to Mongolia and Sinkiang (Eastern Turkestan). Every year the city is busy with camel caravans going to and from these places.

Merchandise destined for this long journey comes from foreign countries as well as from the interior Provinces of China. It is assembled in Kalgan and thence shipped down the Peking-Suiyuan railway to Kweihwa, or Paotowchen, to be transported by the ancient method of camel caravans. Cloth, bricks, tea, flour, sugar, cigarettes, ironware, matches and kerosene oil are the principal commodities.

Recent military operations in north-western China, particularly around the Peking-Suiyuan railway, have somewhat curtailed the movement of goods, but under normal conditions Paotowchen alone annually distributes throughout Mongolia and Sinkiang about 10,000 bundles of cloth; £60,000 worth of tobacco, £80,000 worth of cigarettes; 13,000 chests of brick tea; and 540,000 catties (or 720,000 pounds) of ironwares; a large proportion of the kerosene oil and flour mentioned, and a small amount of sundry goods.

Upon reaching Paotowchen, the merchandise is turned over to certain traders for further redistribution. There are about 30 such traders who carry on an extensive business. The more prosperous ones generally own anything from 200 to 800 camels, while others hire the animals from local caravaners. In the late spring the animals are turned loose on the Mongolian pasture lands and resume work again in the autumn, thus avoiding travelling in the summer months, which is the rainy season in Mongolia. In September they are brought in from the pasture lands and packed with wares ready for delivery to Sinkiang and points *en route* in outer Mongolia. Each camel usually carries two packages of 140 catties each, or a total burden of nearly 400 pounds.

Radiating from Paotowchen are numerous caravan routes. A very important route runs to Urga, in Mongolia, and is a well-beaten track from centuries of use. There are two well-traversed routes—the northern and the southern—from Paotowchen to Kucheng and Tihwa (Urumichi), important trade centres in Sinkiang. The northern route follows the Peking-Urga trail, running directly north until it intersects at Sairussu with the main post road going from Kalgan to Uliassutai and Kobdo in outer Mongolia. The early part of the journey is over Mongolian pasture lands. On the way small Mongolian villages are passed, and caravaners barter wares with the inhabitants; but the wants of these Mongols are few. They are a nomad people who prefer to leave agricultural pursuits to the Chinese, while they herd cattle from the saddle of a pony and move from place to place in search of new grass lands. Their houses are in the order of tents, called “yurtas,” made in circular fashion of lath or cane framework covered with felt. They are collapsible, so as to be easily moved when it is time for the semi-annual migration to new grazing grounds. The Mongols supply Paotowchen annually with approximately 90,000 sheep, 10,000 horses, 9,000 cattle, and a large number of camels.

From the Kalgan-Kobdo post road there are several trails dropping south to

Kucheng and Tihwa, where the camels are unloaded and the traders exchange their goods for the wool, skins, furs, and sundry goods of Sinkiang.

The trip by the northern route covers approximately 1,800 miles, and takes about 70 days. In view of the heavy transit tax, and, sometimes, ill treatment at the collectorates in outer Mongolia, however, some caravaneers prefer to go to Sinkiang by way of Ala-Shan, along the Kansu border. This is the popular southern route. The journey is circuitous and requires about 100 days. It is divided into a little over 60 stages, each 20 or 35 miles from the next. The first two sections of the trip, from Paotowchen to Ningsia and from Ningsia to Lanchow, may be made by motor bus, although from Ningsia to Langchow the going is exceedingly difficult because of the high passes and desert stretches. When the trip is made from Paotowchen entirely by camel caravan, a route running farther north of the motor route, through the Ordos territory, is used, as fodder for the animals can be obtained more readily in the Mongolian steppes. This route follows the Kansu border into Sinkiang.

In 1924 Sinkiang and Mongolia transported to China, by this method, 13,876 loads of skins and furs and 5,729 loads of sundry goods.

EARTHQUAKE RECONSTRUCTION IN JAPAN.

According to the Annual Report by the Commercial Secretary to H.M. Embassy at Tokyo, the reconstruction of the two principal cities of Japan—Tokyo and Yokohama—which were severely damaged by the earthquake of 1923, has been disappointingly slow. The preliminary work of adjusting land in accordance with town-planning and street-widening requirements has proved a laborious task. So far as Tokyo is concerned, it may be said that little has been done in the way of permanent construction to replace temporary buildings. The latter have been given until August, 1928, as a period of grace during which they are exempted from compliance with the town planning regulations. Some new construction is of course, proceeding, but in general the temporary erections put up hurriedly after the earthquake remain typical of the buildings in the devastated areas.

In Yokohama the restoration of the Customs compound and wharves has been followed by the reconstruction of the pier used by mail steamers, which now shows a great improvement over the structure destroyed in the earthquake. A fine new silk-conditioning house has been erected to replace the old one which had been repaired after the earthquake for temporary use. Large modern warehouses have also been built for the special purpose of storing silk. A conditioning house for silk tissues is to be built during the present year.

In the former foreign settlement private firms have in a few cases erected substantial office buildings and warehouses. Progress in this district has of necessity been delayed until the conclusion of negotiations regarding land readjustments connected with street-widening. Plans to settle this question have been approved by the Japanese authorities and local landowners and perpetual leaseholders, though they still require the approval of leaseholders resident outside Japan. The municipality has also bought up a number of perpetual lease lots. Once the boundaries of property are definitely decided, a rapid increase of permanent building may be anticipated, since a number of firms have plans under consideration. Meanwhile work has been started on a large foreign-style hotel and a foreign club, and the present year should see the reconstruction of local government offices, law courts, etc., taken in hand. The location of the new prefectural offices upon their old

site facing one of the roads which bounds the former settlement is taken as a good augury for the recovery of its importance by the district in which the foreign business houses are mainly located. The number of British and other foreign residents has increased greatly during the last two years, many whose business is now in Tokyo preferring to live in Yokohama.

Meanwhile the municipal reconstruction of roads, bridges, sewers, drains, etc., and the refacing of the canals is proceeding in both cities.

THE DECLINE OF JAVA COFFEE.

Java coffee gained its reputation for fine quality in former days when practically all the coffee plantations in Java and Sumatra were owned or indirectly controlled by the government of the Netherlands Indies.

Under the "cultuur" system, or forced cultivation, coffee was bought by the government and held in storage for several years, during which it underwent a mellowing or ageing process. Officials took much pride in the quality of coffee that was shipped to European markets, and native overseers were given special compensation for the production of coffee of good quality. The cultivation and marketing of coffee was a government monopoly from the early part of the nineteenth century, with the exception of the period during which the island was controlled by Great Britain, until 1905, although it was not until in 1918-19 that all cultivation by the government was discontinued.

According to the official United States "Commerce Reports," the so-called "Java" coffee—in reality *Coffea arabica*—was successfully introduced into Java about 1699. This type flourished under the system referred to above, but unfortunately it has few qualities of resistance, and when the leaf disease known as *Hemileia vastatrix* appeared in western Java and spread slowly over the island, many plantations of fine Java coffee were destroyed. To-day there are only a few plantations producing the real Java coffee, and these to do so must be located at an altitude between 3,000 to 4,000 feet in order to escape the ravages of diseases. This type, together with *Liberica*, has been almost entirely abandoned in favour of *Robusta*, a type introduced about 1900 and found to be more resistant to the leaf disease, although it has in turn fallen a prey to "koffiebessenboeboek" a coffee borer which appeared in western Java about 12 years ago.

There are but few firms dealing in what was formerly known as "genuine" Java coffee, since the amount produced is insignificant. It is a rare privilege to be served with this coffee even in Java. There are certain resorts, however, where the berries are gathered by the natives and sold to resthouses, hotels, and sanatoriums. *Coffea arabica*, or Java grade, is still grown in considerable quantities in the outer possessions of Sumatra, Celebes, Bali, and Timor. It is the same kind as Java, except for the fact that it is not grown on the island of Java. The soil and climate are the same as on the island of Java, and while the present Java and Java grades may not be considered equal to the "Old Government Java" (owing, perhaps, to the fact that the mellowing process does not extend over a year or so, but takes place during the ocean voyage to points of destination) at least such Sumatra coffees as Mandheling, Ankola, Padang Interior, and Kroe have the reputation of being among the finest and highest priced coffees at present produced in any region. They are grown on what were formerly government estates.

The total commercial production of coffee of Java and Java grades on the island of Java and in the outer possessions has dropped to 15,352,224 pounds, compared with 34,264,928 pounds for the island of Java alone around 1900, and with 174,945,240 pounds in 1879!

GENERAL NOTE.

MORRIS EXHIBITION.—An Exhibition illustrating the art and craft of William Morris will be held at the Fulham Central Library, 598, Fulham Road, S.W.6, from June 4th to 18th, 1927, inclusive. The following lectures will be given during the Exhibition: "The Art of William Morris," by Miss May Morris; "The Kelmscott Press," by Holbrook Jackson, Esq.; "Morris and Ancient Buildings," by A. R. Powys, Esq.; "William Morris as Literary Artist," by J. H. Greenwood, Esq. The hours of opening are 1 p.m. to 8 p.m. each weekday, except Whit Monday, and there is no charge for admission. Further particulars and dates of lectures may be had on application to the Borough Librarian.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, MAY 30. Architects, Royal Institute of British, 9, Conduit Street, W. 8 p.m. Mr Thomas Hastings, "Devonshire House Buildings"

Farmers' Club, at the ROYAL SOCIETY OF ARTS, Adelphi, W.C. 4 p.m. Mr. G. Holt-Thomas, "Three Times Milking."

Geographical Society, at 135, New Bond Street, W. 8.30 p.m. Mr. W. F. P. Burton, "Central Katanga."

Surveyors' Institution 12 Great George Street, S.W. 5 p.m. Annual General Meeting.

Victoria Institute, at the Central Hall, Westminster, S.W. 4.30 p.m. Professor Dr K. Dick Wilson, "The Radical Criticism and the Psalter"

University of London, at King's College, Strand, W.C. 5.30 p.m. Dr G. P. Gooch, "Some Modern English Historians" (Lecture V.) "Acton"

5.30 p.m. Mr. Henry Wickham Steed, "Hungary and Roumania."

At the London School of Economics, Houghton Street, Aldwych, W.C. 5 p.m. Mr. G. V. Portus "Political Theory and Economic Experimentation in Australia." (Lecture III.)

At the London School of Medicine for Women, 7, Hunter Street, W.C. 5.30 p.m. Prof. H. Beckwith Whitehouse, "The Menstrual Function, its Physiology and Pathology." (Lecture III.)

At University College, Gower Street, W.C. 4.30 p.m. Prof. Dr. Sir Flinders Petrie, "Recent Discoveries in Palestine" the City of Gerar"

TUESDAY, MAY 31 Chadwick Public Lecture, at the Chelsea Physic Garden, Swan Walk, Chelsea Embankment, S.W. 5 p.m. Mr. B. Gerritsen, "The Growing, Marketing and Exporting of Fruit and Vegetables in the Netherlands"

University of London, at Guy's Hospital Medical School, St. Thomas's Street, S.E. 5.30 p.m. Prof. Dr. E. H. Kettle, "Inflammation and Infection." (Lecture III.)

At University College, Gower Street, W.C. 5.30 p.m. Mr. W. H. McLean, "National, Regional and Town Development Planning" (Lecture IV.)

WEDNESDAY, JUNE 1. University of London, at King's College, Strand, W.C. 5.30 p.m. The Rev. W. R. Matthews and the Rev. Canon Francis Underhill, "The New Prayer Book." (Lecture IV.)
At the London School of Economics, Houghton Street, Aldwych, W.C. 5 p.m. Mr. C. S. Orwin, "The Economics of Agriculture." (Lecture III.) 5 p.m. Dr. Hubert Hall, "Housekeeping in Six Centuries (1200-1800)." (Lecture VI.)

THURSDAY, JUNE 2 Chemical Society, Burlington House, W. 8 p.m. (1) Mr. U. R. Evans, "The Passivity of Metals. Part I.: The Isolation of the Protective Film" (2) Messrs. T. M. Lowry and R. R. Goldstein, "Studies of Valency Part VIII: The Molecular Structure of Vernon's Dimethyltellurium Salts," (3) Messrs. E. Roberts and E. E. Turner, "The Factors controlling the Formation of some Derivatives of Quinoline, and a new aspect on the Problem of Substitution in the Quinoline Series."

University of London, at the London School of Economics, Houghton Street, Aldwych, W.C. 5 p.m. The Hon. Mr. Justice Wright, "Insurance against War Risks at Sea."

At University College, Gower Street, W.C. 5.30 p.m. Prof. Dr. Edmund G. Gardner, "Venice and the Political Thought of the Renaissance"

FRIDAY, JUNE 3. Physical Society, at the Imperial College of Science, South Kensington, S.W. 5 p.m. Dr. E. H. Rayner, "The Forthcoming Eclipse of the Sun"

Royal Institution, 21, Albemarle Street, W. 9 p.m. Dr. George M. Trevelyan, "Carlyle as an Historian."

University of London, at Guy's Hospital Medical School, St. Thomas's Street, S.E. 5.30 p.m. Prof. Dr. E. H. Kettle, "Inflammation and Infection." (Lecture IV.)

At King's College, Strand, W.C.2. 5.30 p.m. Monsieur Denis Saurat, "Marcel Prôust" (in French). (Lecture III.)

5.30 p.m. The Rev. Claude Jenkins, "Some Views of Divine Communications in Latin Literature."

At the London School of Economics, Houghton Street Aldwych, W.C. 5 p.m. Mr. Philip Noel Baker, "The Economic Conference held at Geneva May, 1927." (Lecture II.)

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All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2.)

NOTICE.

DOMINIONS AND COLONIES SECTION.

TUESDAY, MAY 31ST, 1927. SIR CHARLES STUART-BAYLEY, G.C.I.E., K.C.S.I., in the Chair.

A paper on "Spanish Morocco" was delivered by SEÑOR DON TOMAS BALDASANO, LL.D., Caballero de Isabel la Catolica, London correspondent of La Epoca. The paper and discussion will be published in the *Journal* dated July 29th.

PROCEEDINGS OF THE SOCIETY.

SEVENTEENTH ORDINARY MEETING.

WEDNESDAY, MARCH 30TH, 1927.

MR. CHARLES B. L. TENNYSON, C.M.G., Deputy Director, Federation of British Industries, in the Chair.

The following paper was read :—

BRITISH FILMS.

By COLONEL SIR ARTHUR R. HOLBROOK, K.B.E., M.P.

In the House of Commons, in the early part of 1925, Mr. Baldwin, the Prime Minister, said :

" There is one subject on which I would only say one word, and that is the film industry. I think the time has come when the position of that industry in this country should be examined with a view to seeing whether it be not possible, as it is desirable on national grounds, to see that the larger proportion of the films exhibited in this country are British, having regard—and I put this

to the whole House—to the enormous power which the film is developing for propaganda purposes, and the danger to which we in this country and our Empire subject ourselves if we allow that method of propaganda to be entirely in the hands of foreign countries.”

Since the Prime Minister made this statement, the importance of the question of British Films has been freely discussed in the Press and in Parliament. It was made one of the leading features of debate at the Imperial Conference, and it has occupied the attention of the Federation of British Industries and of Chambers of Commerce.

When I agreed to introduce the subject for discussion by the members of the Royal Society of Arts, there did not appear to be the possibility of immediate legislation, although Sir Philip Cunliffe-Lister, the President of the Board of Trade, had made it clear that the Government intended to deal with it by some form of legislation. The delay in such legislation is not attributable to any want of sincerity on the part of the President of the Board of Trade or of the Government, but it has been most difficult to obtain from those engaged in the industry any lead or any practical suggestions as to the lines on which legislation could be framed, to secure the production and exhibition in this country and throughout the Empire of films which would portray British life and character. It may be well first to consider the information we possess with regard to the early invention of Cinematography, and I would preface my remarks on this point by saying that Britishers took a fair share in these early efforts.

EARLY INVENTORS OF CINEMATOGRAPHY.

As has been said before, “It is a wise invention that can single out its own inventor.” The claim to the discovery of moving pictures can scarcely be sustained by one man. About the middle of last century Dr. Horner, of Bristol, invented the Zoetrope or Wheel of Life. This was a toy designed to illustrate the law of “Persistence of Vision,” and a very ingenious toy it was. It consisted of a small cylinder, mounted on a vertical spindle in such a way as to be free to revolve horizontally. Upon the lower half of the inner surface of this drum was mounted a paper band, on which was a series of pictures, usually silhouettes, depicting successive stages of movement, such as a horse jumping over a gate, a child skipping, and so on. The upper half of the cylinder was pierced at regular intervals by long, narrow, vertical slits. If you sat before the toy so as to look through these slits with a fixed gaze, and then rotated the drum, the pictures appeared to depict movement. It was this toy which set inventive brains in Europe and America thinking along the lines of cinematography.

The illusion of moving pictures had been proved possible by this machine, or rather toy, and with drawings, not photographs. Photography had not yet entered into the field of moving pictures, but it did, in 1872, and it was an

Englishman, one Edward Maybridge, who first applied photographs to the Wheel of Life, and similar machines. Each of his dozen or so photographs, however, was taken by a separate camera. This sort of procedure was, of course, far too complicated to lead anywhere, so inventors now turned towards devising a special camera for the taking of these pictures.

Among the early workers in this direction were the Englishmen, Friese Greene and Evans, who took out a patent for their Chrono-photographic apparatus in June, 1889. Two months previously, in April, 1889, another inventor, Stern, had also filed a patent, and these constitute the first intimation at the British Patent Office of the advent of Cinematography.

These men, Friese Greene, Evans, Stern, Dr. Marey (of Paris) and George Demeney and others, all working towards the same goal, were handicapped by the fact that they were forced to take their pictures on glass. Mr. Eastman, of Kodak fame, had not yet invented the one thing which remained to make cinematography, as we know it to-day, an accomplished fact—the roll film.

Though Mr. Eastman and others had been experimenting for some years, it was not until 1889 that he produced what was then considered to be a comparatively satisfactory roll film base. The first man to take advantage of this new photographic base was one near at hand, a now famous American, also one of the pioneers, Thomas Edison. To him it was the missing link, and in a very short while he was taking cinematograph pictures more or less as they are taken to-day—but *he* was content for the time being, at any rate, to go a very little step further than the Wheel of Life, and only exhibit short lengths of film in a cabinet, working on the coin in the slot principle.

To an Englishman must go the credit of seeing further than Edison; he realized that there was no commercial value in films if only one person could view the pictures at a time. This Englishman, Robert Paul, not only very soon, like Edison, invented a camera to take moving pictures on roll films, but also devised an apparatus for projecting his pictures on a screen. This he achieved in 1895. And the first demonstration of moving pictures as we know them to-day was given in February of the following year. This was given by Paul himself at the Finsbury Technical College, London, and a few days later, on February 28th, 1896, his whole apparatus was exhibited in the library of the Royal Institution of Great Britain before a distinguished audience of scientists and their friends, amongst whom was Lady Harris, wife of the famous impresario, Sir Augustus Harris. The following morning, Robert Paul received an urgent call from Sir Augustus, with the result that in a very few days he was showing his moving pictures at Olympia, as a complete entertainment.

AMERICAN DOMINATION OF THE INDUSTRY.

The majority of the discussions about the British Film industry ignore the salient factors of the case. Why are the majority of films made in the U.S.A.,

and why can they be imported at a price which renders the British Film Industry unprofitable to run ?

The majority of films are made in California, for the simple reason that the weather in that area is remarkable for the strength of the sunlight and the absence of dirt and dust in the atmosphere. There is an absence of cloud and fog such as cannot be realised in this country. Weather, in fact, can be relied on in making arrangements. This means that the number of potential working days in the year is considerably greater than it is in this country.

The second ground is that the home market provided by the area of the U.S.A. consists of over one hundred millions of people, two-and-a-half times our own, and it is protected in the same way that other American industries are protected. Thus the American film manufacturer is independent of foreign markets, which he can afford to swamp at uneconomic prices.

The most profitable part of the films produced is of low quality. The better quality films are more expensive to make and command a smaller audience. Hence the system of "block-booking," which is mixed up with the system of "blind-booking."

Under the first term is included the practice of booking so many of one class of film and so many of another, regardless of whether these proportions are desirable, and whether the films themselves are wanted. Under the second term comes the system of booking films before they are, in fact, made. "Trade shows" are given of films which do not, in fact, appear in public till at least eighteen months later.

There is, therefore, a close monopoly based on the accidents of climate and population, protected by tariff walls, and worked in this country by those interests in the trade which are not interested in the films in which they deal, nor yet in the people to whom they are shown.

The convenience and ubiquity of the picture house, with its continuous show, and comparative cheapness compared with the theatre, has encouraged the decay of the habit of thinking, never at any time popular with the bulk of the population.

HOW TO REVIVE BRITISH FILM INDUSTRY.

The present position of the British film industry is that no agreement exists. Legislation has been desired to enforce a British quota in every programme exhibited. I have referred to the difficulties with which the President of the Board of Trade has been faced in his efforts to introduce legislation to ensure that Britishers, at any rate in this country and throughout the Empire, shall have the opportunity of seeing pictures that shall reflect British life and character. I propose, therefore, to recount the various efforts made in this direction.

JOINT TRADE COMMITTEE.

A Joint Trade Committee was set up to consider the question. The final paragraphs of their report were as follows :—

“ The interest of the manufacturers or producers would be satisfied by any chance scheme which assures them an outlet for their films. This outlet may be found either by an obligation which compels renters to acquire a certain number of British films, or by an obligation upon exhibitors to take a certain proportion of British films when produced, which, in the normal course, they would hire from renters. Renters marketing British films would be satisfied with a scheme that would secure the exhibition of films which they might be compelled to acquire. Exhibitors would be satisfied to participate in a scheme which would secure for them a certain and sufficient supply of British films of suitable quality and price, but the safeguards to any compulsory scheme . . . so far proposed, have failed to remove the apprehensions of the general body of exhibitors. The Committee regrets it is unable to make any further recommendations that would be likely to produce an agreed scheme as desired.”

“ The Committee endeavoured to formulate a scheme which would achieve the following objects :

- (1) To increase the quantity and proportion of British films screened in the United Kingdom and elsewhere.
- (2) To establish an industry under British control in the United Kingdom for the production of these films.
- (3) To encourage the production of such films as will, directly or indirectly, give employment to British labour at home, and increase the prestige of the British name, British Institutions and British manufactured products at home and abroad.

“ It is believed that any scheme satisfying the foregoing objects would meet the views of the Government on this subject, as outlined in interviews and correspondence with the President of the Board of Trade. . . .”

“ In approaching the problem, the economic conditions which prevail in the British market must be borne in mind. British film production at the moment is on a small scale, and any increase must be affected by the markets available. British films cannot at the present time depend upon a market in America owing to the fact that that country produces an ample supply of films for its own home consumption. On the other hand, every American film, after a run in a home market four to five times as large as our own (according to the number of cinemas), or six to eight times as valuable (according to the box-office receipts), is available to be offered for sale in this country with its negative cost having already been covered.”

“ British films have to cover their entire negative cost from the smaller British market owing to the absence of the American market, whilst American films can be sold in this country at a price equal to a very small portion of their original cost. This state of affairs in turn tends to limit the character of British films that can be produced, because pictures of international appeal generally call for a greater expenditure than the British market can normally sustain. British films are further handicapped in foreign countries, and even in our own Dominions, by having to meet the competition of American films which can be sold at very low prices. In many of these countries and Dominions the market is controlled by or through American interests.”

BLIND BOOKING.

"There is another class of picture, mainly for domestic exhibition, which does not call for the same expenditure, but which is precluded from obtaining a sufficient number of exhibition dates by reason of the severe unrestricted competition from the foreign film. If British films could obtain a wider exhibition in this country, their production would be remuneratively possible. Renting these films is made more difficult for the British distributors by reason of the present methods of booking, which enable whole outputs of American films to be booked in advance, and often without having been seen. British films have, in consequence, to suffer the further handicap of being postponed to exhibition dates not already booked under an output contract. This last state of affairs has been recognised, and proposals are being seriously considered by the trade with a view to securing more equitable conditions of trading by the abolition of blind booking."

"The Committee consisted of representatives of manufacturers, renters and exhibitors. It met with an eager desire to find a solution. Its efforts resulted in the only scheme the Committee has agreed, referred to later in the report as the 'Quota' scheme. When this scheme was submitted to the various sections it secured the approval of the manufacturers and renters, but although it obtained the approval of a majority of the general council of the Cinematograph Exhibitors' Association, it was defeated on a referendum of members. Following that event the Committee was no longer able to put that scheme forward as an agreed solution by the whole of the trade. It was requested 'to reconsider the whole position and to make other recommendations,' and the Committee was enlarged. This Committee has deliberated on many occasions, and considered all the proposals submitted. A Sub-Committee which was appointed accepted an invitation from the President of the Board of Trade to meet him on March 12th, 1926, and his statement on behalf of the Government has largely governed the Committee's further deliberations."

"QUOTA" SCHEME.

"Various suggestions were made at sectional meetings of the trade, but ultimately, after all these had been examined in detail, they indicated that no scheme was likely to satisfy the objects set out in the problem which did not include the quota. Accordingly it was remitted to a Sub-Committee to prepare the detailed scheme, which provided for an obligation upon renters to rent a proportion of British films, as a condition of renting foreign films, and an obligation upon British exhibitors to exhibit a corresponding proportion of British films.

"This scheme raised grave apprehensions in the minds of exhibitors. Doubts were expressed whether British films of a suitable quality for exhibition would be forthcoming in sufficient numbers and at a suitable price, and there was a real apprehension that British producers might create a monopoly value for their 'Quota' products. Reference to the safeguards provided failed to allay these doubts, because exhibitors feared the constant interruption of their business through the necessity of making frequent appeals to some statutory authority.

"The Committee then discussed the possibilities of imposing a compulsory obligation only upon renters who would acquire a certain number of British films as a condition of being allowed to import a proportionate number of foreign films. The Committee failed to agree, and held the view that there was no guarantee that any films which they so acquired would secure exhibition upon the screens,

and therefore in that event the proposal would not fulfil the conditions necessary for a solution of the problem. The Committee then considered the possibility of imposing a compulsory obligation upon renters, coupled with a voluntary undertaking upon the part of exhibitors, but the Committee failed to formulate any scheme that the producer and renter members regarded as likely to give sufficient security for the investment of capital. The Committee next considered the possibility of a quota obligation being voluntarily applied to renters and exhibitors, but came to the conclusion that no solution to the problem would be found in that direction, there being no guarantee or likelihood that the voluntary obligations would be fulfilled. The Committee has also considered the "Kontingent" system as in operation at present in Germany. The Committee is agreed that a fifty per cent. "Kontingent"—that is, a ratio of one foreign film to one native film—could only be applied in a country having a much greater native production than there is at present in this country."

RECIPROCITY SCHEME.

"Having regard to the economic factor, the Committee has always been very sensible of the fact that the exhibition of British films in America would materially facilitate British producers in their efforts to increase British production. The Sub-Committee, on March 16th 1926, met the London representatives of the American houses to consider the principle involved in reciprocal arrangements for the exhibition of British films in America when the representatives promised to consult their principals in America. Further consideration was given to the matter at a meeting held on April 21st, but at that date the American representatives were not in the position to communicate a reply. In the course of discussion the question arose as to what conditions would fulfil the Government's definition of a British film. Accordingly, while the Sub-Committee was waiting for a reply from the American representatives, the President of the Board of Trade was invited in a letter of April 22nd to express his views. The General Strike intervened. On May 28th, although the American representatives had no definite information to communicate as to the attitude of their principals, there was a sufficient feeling of optimism to proceed with further discussions of a reciprocity plan. A plan was drafted and submitted to the American representatives on May 31st, which Colonel Lowry, the representative of the Motion Picture Producers' and Distributors' Association (the Hays' organization) promised to transmit. This plan was considered by the Committee on June 9th.

"In return for the arrangement the Sub-Committee undertook to recommend the adoption of the plan (a) by this Committee, (b) by the Government, (c) by the public and the Press. When, however, the Sub-Committee made its recommendations to this Committee, there was general support for the principle of reciprocal arrangements with America, but some members strongly criticised (a) the scheme, fearing that it would mean an American monopoly of distribution of British films, (b) the definition of a British picture, and (c) the absence of an equal opportunity among British producing units of participating in the production of British pictures that would be made for release in America. Further, fears were expressed that any reciprocal scheme would fail owing to the difficulties of enforcement, as it would rely for its fulfilment upon what is known as a 'gentleman's agreement.' The scheme in principle commended itself to the Committee, and it was adjourned for further consideration to ascertain whether certain expressed fears and apprehensions could be removed within the scheme. The results of the Committee's deliberations were conveyed to Colonel Lowry for communication

to America, in order that formal approval might be given to the principle, and that authority might be obtained to negotiate a full scheme based on these principles. As no reply had been received to this request, the Committee passed the following resolution at a meeting on July 6th: 'That in the absence of any message from America giving approval in principle to the reciprocal proposals, the Committee consider that no useful purpose would be served by giving detailed consideration to them at the present time.'

ENTERTAINMENTS TAX.

"Another suggestion was put forward that if the Government's interest in the question extended to the possibility of a remission of entertainment tax where the entire programme consisted of British pictures, such action would give a great stimulus to British production. Although this suggestion was at one time made to the President of the Board of Trade, it has not been explored at any length, and the Committee does not know whether the Government is prepared to consider it. If any indication is given by the Government, a scheme could be prepared showing how any tax remitted would find its way to stimulate British production."

In conclusion the Report states:—

"The Committee has had numerous schemes submitted to it. Many of these schemes provide machinery for the operation of a 'quota,' and are not referred to in detail at the moment, being largely governed by the principles underlying the main 'quota' previously referred to, or would only fall to be considered if the trade as a whole was favourably impressed with any compulsory 'quota' scheme. Various schemes involving import duties varying with the country of origin of the films have been referred to the Committee, but these cannot be seriously considered, owing to the infraction of international treaties. Suggestions have been made for a reel tax levied on the exhibition of foreign films, but such a tax would be most unfair in its incidence. A reel tax might not be a hardship to a hall with a large money-holding capacity, but would inflict a serious burden on the smaller halls throughout the country, and, in any case, would not solve the problem. Schemes for finance corporations have been put forward, either for assisting producers with loans or for participating in co-operative production, but in the absence of an assured outlet, it has been felt that there is no greater opportunity of finding in the future the requisite amount of finance than at present, nor has any indication been given that the requisite finance which any scheme contemplated would be forthcoming."

THE IMPERIAL CONFERENCE, 1926.

I have told you that at the Imperial Conference last year attention was given to the subject of the encouragement of the production and exhibition of Empire films. There was agreement as to the great importance of dealing with this matter, having regard to the influence exerted by the cinema, considered from the general cultural and social point of view as well as with reference to the development of trade, and to its potential value as a means of giving the people of the various parts of the Empire a more vivid realisation of one another's lives and surroundings. The question was referred for consideration in detail with other economic questions to a General Economic Sub-Committee.

The Sub-Committee pointed out that in all parts of the Empire only a small

proportion of the films exhibited are of Empire production ; few Empire films are produced, and the arrangements for the distribution of these are far from adequate. State action could contribute to the solution of the problem, but could not be effective unless by private enterprise a substantial output of films of real and competitive exhibition value was attained, and satisfactory distributing arrangements were developed throughout the Empire. Various suggested methods were considered by means of which the several Governments might assist in securing a larger production within the Empire of films of high entertainment value and films of sound educational merit, and their exhibition throughout the Empire and the rest of the world on an increasing scale. It was recognised that circumstances vary in different parts of the Empire, but the opinion was expressed that any action which it might be found possible to take in Great Britain, the largest producer and largest market for films in the Empire, would undoubtedly be of the greatest assistance to the other parts of the Empire in dealing with the problem.

On the recommendation of the Sub-Committee the Conference adopted the following resolution :—

“ The Imperial Conference, recognising that it is of the greatest importance that a larger and increasing proportion of the films exhibited throughout the Empire should be of Empire production, commends the matter and the remedial measures proposed to the consideration of the Governments of the various parts of the Empire with a view to such early and effective action to deal with the serious situation now existing as they may severally find possible.”

GOVERNMENT BILL.

I told you at the outset that when I agreed to read this paper no disclosure had been made as to the lines on which the Government proposed to introduce legislation on the subject. The Cinematograph Films Bill has, however, now been introduced, the subject has been fully debated in the House of Commons, and last week a second reading was given to the Bill, which will no doubt be amended in some particulars in Committee.

The Bill is divided into four sections. In the first section the restrictions on blind booking and advance booking of films are set out, and the interesting point is made that any agreement entered into before the passing of the Act which would be illegal if made after that date, will cease to have effect in so far as it relates to any films to be delivered for public exhibition after March 31st of next year. Many contracts have already been made for the delivery of films for two or three years ahead, and these agreements will consequently be void if delivery cannot be effected before the end of March, 1928, a proposal that will excite some opposition.

From the beginning of next year, according to Part II of the Bill, which deals with the registration of films, every film, whether British or foreign, which is to be shown in this country will have to be registered with the Board of Trade, with the exception of certain classes of film, such as news bulletins and nature studies, which do not come within the scope of the Bill.

If the Board of Trade refuses to register a film as British the matter may be referred to the High Court. Every film will have to be marked with its registered number and length, but there is apparently no compulsion on the exhibitor to reveal to the public the fact that he is exhibiting British pictures.

The quota is dealt with in Part III of the Bill. It requires that every renter shall acquire, for the purpose of renting to exhibitors, a minimum length of registered British films as laid down by the schedule to the Bill. The quota begins at $7\frac{1}{2}\%$ for next year, advancing by yearly increases of $2\frac{1}{2}\%$ until the maximum of 25% is reached in 1935. The same quota is imposed on the exhibitor, with the exception that it starts a year after and that each year the quota imposed on the exhibitor is one stage lower than that imposed on the renter. The Board of Trade have deliberately begun with a low quota, since it was felt that in order to stimulate competition among British producers, the figure should be below the British output.

It is computed that last year British films constituted 3 per cent. of the total films shown in this country, and this year the figure is estimated at between 4 and 5 per cent.

In the fourth part of the Bill a list is given of exempted films, and an attempt is made to describe what constitutes a British picture—one of the most difficult tasks that have confronted those who have had to frame the Bill. It also gives the Board of Trade power to set up an advisory committee, consisting of two representatives of film makers, two of film renters, four of film exhibitors, and three members, of whom one is to be the chairman, who have no pecuniary interest in any branch of the film industry.

It is not intended that the Board of Trade should appoint a large staff of inspectors to see that the conditions of the Act are observed. It is thought, in fact, that the whole work can be carried out at a cost to the Department of between £4,000 and £5,000 a year. This cost will be met by the imposition of a small registration fee on every film that is submitted.

There is no intention to introduce any form of Government censorship. The sole object of registration is to differentiate between British and foreign films.

It will be conceded by all that some definite form of State intervention in the regulation of the industry had become necessary. The film is a great engine of publicity, and the dominance of the cinemas by the foreigner (as has been pointed out by a writer in the Press) might well become a greater danger to our English civilization than even our defeat in the late War would have been. The proposals in the Bill have been freely criticised, but, in the absence of any constructive suggestions to remedy the present state of affairs, every loyal Briton will welcome the fact that the Government has shown its determination to move in the matter.

CRITICISMS OF THE BILL.

The debate on the provisions in the Government measure to restore the

British Film industry was marked by a certain tone of uneasiness as to its method and effects. But no constructive proposals were submitted by the critics. The Leader of the Opposition, in a half-hearted way, favoured the idea of a subsidy, and the complaint from the Liberal benches, voiced by Mr. Runciman, was that the Bill will give a guaranteed market to British films unconditional upon either quality or price. The best defence of the measure was, perhaps, that it would free the exhibitors from foreign tentacles, and envelope them with British tentacles.

Excellent provisions are contained in the Bill to secure genuine British pictures in the quota. Films produced by a foreign company in this country will not be admissible, unless that company forms a subsidiary company here with British capital. Even then the films turned out will have to be based on a story either written by a British author, or adapted for filming by a British scenario writer, and the bulk of the salaries and wages paid must be paid to British subjects.

The quota system, while supported in some quarters, has come in for scathing criticism from other directions. One chairman of an all-British film producing company asserts that not only will the quota fail to benefit British producers, but that it will cripple British film production beyond recovery. Sir Oswald Stoll, whose opinion must be received with respect, says the quota ensures for all time that at least 75 per cent. of the screen space and screen values in Great Britain in feature pictures will be reserved to non-British films. He further argues that non-British companies will be able to extinguish British companies by reason of the fact that while the pictures of the latter are restricted to 7½%, rising in eight years to 25% of our home market, the pictures of the former will have an equal share in our quota market plus the remainder of our home market, plus their own home market and the markets of the rest of the world.

It will surprise many that the Socialist party showed determined opposition to the Bill, but some may be induced to change their minds when they learn how strongly it is supported by the Labour organisations representing those who are employed in the entertainment industry. The importance of the film industry from a Labour point of view is instanced by the fact that the biggest film concern in Hollywood pays £200,000 a week in salaries. There are men and women getting from £400 to £600 a week whose talents did not earn them a comfortable income on the stage in London.

When experts in the trade differ so widely in their opinions it is difficult to form a correct judgment as to the effect the proposed legislation may have on the industry, but with the opinions gathered there will no doubt be amendments concerning administration when the Bill reaches the Committee Stage. But if the Bill produces no other effect its promoters at any rate will be able to claim that at long last they have aroused keen interest in the question, and the ultimate effect cannot be otherwise than beneficial to the British Film industry.

Our Dominions are giving us a lead in the matter. In Victoria the Legislative Council have decided that no fewer than 1,000 feet of British films must be shown in every programme, and this will be enforced from the 30th June next. A vigorous campaign is also being waged in other provinces in Australia against the monopoly held by foreign film rights.

THE GOVERNMENT AND THE QUOTA.

I do not know the Government's definition of a British film, for quota purposes, but that drawn up by the Ormiston Committee (a committee appointed by the trade to look into the whole question of British films in regard to block booking and the quota) allows that every British film produced in the future and shown under the quota *may be* directed by a foreigner.

If the Government adopts this definition, then they might just as well leave the quota alone, for they will, by passing a quota under those conditions, give by legislation to foreign interests the only 5% of our market they do not already possess.

It would mean that every foreign firm could and would produce here, and they would do it with British money, not their own. It would mean, too, that crowds of the less efficient directors in America, who could not get a job over there, would come over and on their own get capital, or be engaged by English producing firms. None of the British film people ever seem to realise, until it is too late, that American directors, especially in past years, who have come over here, would not have done so had they been able to obtain employment in their own country, for the salaries paid there to good directors are much higher than are paid here.

It is conceivable that we may need some assistance from foreign directors in the early stages of the quota scheme. But there is not likely to be enough money available to tempt the best American directors to come over here. And I do not see any advantage to a British producing unit in employing a second-rate American director, even in preference to a second-rate British director.

The Ormiston definition is all very good for "More films made in Britain," but not for "More British Films."

BRITISH RENTERS AND THE QUOTA.

British renters who on the collapse of British films had to fall back entirely on the handling of American films, in order to keep going, will, unless the quota is introduced eventually, find themselves out of business.

Gradually, but slowly and surely, the big American concerns are taking the handling of their films away from the English renter, and going direct to the exhibitor themselves. When this operation is complete where will be the British renting houses without the quota? In the same predicament as the exhibitor—no films to fall back on.

PICTURES IN BOND.

To meet the objection of the exhibitors to any kind of quota being forced upon them, an alternative suggestion has been submitted to me, and I hope it may have consideration. It is to follow the line of action adopted by the Government to save the rubber industry, and is simply the control of the output of foreign films by retaining them in bond. Under such a system, although exhibitors would not be forced by the Government to show a proportion of British pictures, they would sooner or later voluntarily accept them in order to fill their programmes.

Were the system I suggest adopted, legislation would not be necessary. The film bonded stores are already under Government control, and free traders could not effectively raise any objection to the scheme, as there would be no stipulation to limit film importation nor would any extra duty be imposed. Let me explain the scheme :—

Suppose, as a basis for argument, that 520 feature pictures are imported per annum. This would mean an output of ten per week. As all foreign films are held in bond until the duty on them has been paid, my suggestion is that only nine or eight should be released per week, instead of ten, each picture to take its turn for release according to the date of being placed in bond. The output to be lessened in each following year by the issue successively of seven, six and five pictures per week. Were this system adopted, neither the Government nor the trade would have any further worry about blind or block bookings, as under its operation these objectionable practices would be automatically extinguished. If exhibitors booked ahead without seeing pictures there would always be, under the restriction of release suggested, a certain gap in their programmes which must be filled with British pictures. It would also assist in disposing of one of the chief difficulties of the Government measure—the definition of a British film—for the exhibitors would be placed in the position of having to select from pictures made within the British Empire. Such a system would, too, tend to arouse keener competition between the British companies who would realise their obligation to make the best pictures in order to obtain sales, and it would relieve exhibitors of their present fear that under a quota system they would be compelled to accept poor British pictures.

It may be argued that by restricting output of foreign films in the manner suggested, definite dates could not be arranged for their exhibition, but it would be a very simple matter of calculation to fix the date when the release of any film would occur. The restriction would further have the effect of checking the importation of foreign films of the second grade, as these inferior films, if bonded for issue in order of deposit, would delay the chance of the exhibition of feature films.

ARE BRITISH PICTURES INFERIOR ?

We often hear it said that British pictures are inferior, but if you investigate the results of the Trade system of assessing the values of pictures exhibited at Trade Shows, you will find that the proportionate percentage of British pictures marked as first-class is higher than that of any foreign films.

THE WAR AND BRITISH FILMS.

Before the War, up to the year 1914, British Films were flourishing, and producing and renting firms were making money to such an extent that one manufacturer of British films—I think I am right in saying this—made a fortune and retired, as far back as 1915.

A few months after the outbreak of war, practically all film production in this country ceased. Heads of producing firms, producers, artists, scenario writers, electricians, scenic artists, carpenters, etc., either volunteered or were eventually called up for military service. True, a certain amount of spasmodic production was carried on, by men who had been medically rejected or were otherwise exempted. But, to all intents and purposes, British production was dead.

The calling up of men for military service also depleted the staffs of British renting houses.

The outbreak of War, then, was the start of the monopoly of the American films in this country.

Picture theatres *had* to provide films for their patrons ; like plays and variety entertainments, pictures were a necessity, for relaxation and amusements at this time were essential. It is almost impossible to imagine how we should have carried on during those trying years of war without these diversions.

PICTURES HAD TO BE PROVIDED.

At the outbreak of war the four principal countries making films were :—ENGLAND, FRANCE, GERMANY, and AMERICA, and some were produced in Italy. We were at war, so was France, desperately fighting for existence, and therefore unable to continue film production.

Germany during the war carried on making films which, needless to say, never left that country until the cessation of hostilities.

America, then, was the only country to provide the needed films, and she not only provided them for this country, but for every country into which she was able to send them. For two years, until she herself entered into the fray, she was able to do this with her producing units at full strength, and even after her entry into the war, film production was still carried on apace. During those first two years of war, too, America being neutral, her film travellers were able to carry on business in every country in the world.

What was the state of things when the war ended ? Our film people, like those of other trades, only returned gradually, and when the British producing

organisations again got going, they were faced with the fact that there was very little room for British films.

American films were booked up throughout the whole of the country for months, and in some cases for a year, ahead. It soon became apparent how very strongly the American film people were entrenched. And what was the barrage they put up to hold their position? In order to induce the exhibitor to continue to take their films they practically gave them away, and often still do so, or, in other words, rent them out at prices very much lower than the price at which it would be possible to rent a British film of the same calibre.

This was possible, because, until quite recently, the Americans, owing to the enormous size of their home market, have been able to make very handsome profits in their own country before sending their films abroad.

The malady from which the British Film Industry suffers is the malady from which the British Nation suffers—a want of co-operative solidarity. One writer has said that the cake—and it is a cake of over 30 million pounds a year—is shared between the exhibitors and the distributors—British, pseudo-British, and frankly foreign. The foreign producer gets a few useful bites. The British producer gets only the crumbs, should any fall.

It is claimed that the Government Bill is framed to assist the British producer, and it is well, in criticising the proposal, to keep this point in our minds. The producing interest is the keystone of the arch. If that goes all goes, or exists only on foreign sufferance.

If foreign films secure a monopoly in this country, their owners may, by agreement among themselves, put every British distributing firm out of business, and take over every British cinema of any importance, or reduce it to the level of a foreign tied-house, at the expiration of existing contracts. No cure is possible if, as asserted by some persons who should be in a position to know, the British public do not want, and if given, do not appreciate, British films. But I do not accept this assertion as correct. Unless and until the British public can be allowed to choose what films it will see, by having a fair proportion of British films placed in competition with the foreign films with which they are now overwhelmed, no sufficient evidence of their tastes and wishes can be forthcoming.

American films may or may not be the finest the world has ever seen or is ever likely to see. But the fact that they have ousted British films from the British market is not in itself proof of their superior intrinsic merit, however intrinsic merit may be defined. Neither is it evidence of their greater popularity with the British public, for the public have little to say in the matter. For this reason: between the film owner and the public are two intermediate markets—the film distributors and the exhibitors of films.

The American menace is not the only one with which the British film industry is faced. A determined effort is being made by Germany to wrest from America her hold on the British market, and with this intent we are told

that the Ufa Studios are to be turned into the Hollywood of Europe for exploiting German films. We have been notified that a German wonder film is shortly to be given a special presentation in London. This is the work of an ambitious young producer named Fritz Lang, and is named "Metropolis." It is of the Jules Verne type, and concerns life in the year 2027, and its settings are futuristic in the actual sense of the word. Traffic moves on bridges hundreds of feet above the roadway, while aeroplanes circle over fantastic sky-scrapers. It is claimed that the production cost a quarter of a million sterling, and that 37,000 paid actors and actresses were employed. The spectacle of German production on such colossal lines gives cause for reflection.

We are now told that what Germany aims at is not an individual film industry, which it believes cannot live by itself, but at a European Film Trust, in which France, England, Scandinavia, Italy and Germany are to drop their frontier barriers and duties and unite to produce pictures with an appeal to all Europe as strong as the American appeal has been.

BRITISH ENTERPRISE AWAKENED.

But we are not without men of enterprise in this country, and a big scheme for British films is being launched which may make Wembley into a British Hollywood. We are told that the ambitious scheme will require a capital of a million pounds. Some of the best known British authors, producers, actors and artists are said to be associated with the scheme, which aims at producing British films on a large scale to be distributed by an Empire-wide organisation. The actual production, like the authors and artists, will be purely British.

Whatever may be the merits of the Bill introduced by the Government, it is satisfactory to know that it has, at any rate, given courage to British capital and enterprise to consider such a gigantic scheme, and, if it is successful, we may aspire to see the day when British people can have full opportunity of witnessing on the screens pictures conveying a correct idea of British ideals and traditions.

The agitation in favour of British pictures, which has continued during the past two years has led to a remarkable increase in the volume and quality of British production. In the year 1926, there were about five-and-twenty British feature films produced, of which the following were the most important :

<i>Name of Producing Company.</i>	<i>Name of Film.</i>
Gaumont Co., Ltd.	.. Mademoiselle from Armentières. London Love.
Britannia Films, Ltd.	Second to None.
Astra National Productions, Ltd.	.. The Flag Lieutenant.
Archibald Nettlefold Productions	.. The House of Marney.
Stoll Picture Productions, Ltd.	.. The Jungle Woman. Boadicea.
Sandground	.. Life of Robert Burns. Life of Sir Walter Scott.

<i>Name of Producing Company.</i>	<i>Name of Film.</i>
Gainsborough Pictures, Ltd.	.. The Lodger.
British Instructional Films, Ltd.	.. The Triumph of the Rat.
	.. Mons.
	Nelson.
	Palaver.
British National Pictures, Ltd.	.. Nell Gwyn.
	London.

In 1927 there will be thirty-nine British feature pictures, the list being as follows : —

Archibald Nettlefold Productions	.. A Daughter in Revolt.
	Virginia's Husband.
	Summer Lightnin'.
Stoll Picture Productions, Ltd.	.. Pearl of the South Sea.
Welsh Pearson & Co., Ltd.	.. Huntingtower.
	Pinklegs.
British National Pictures, Ltd.	.. Tiptoes.
	Mdme. Pompadour.
	King's Mate.
	Tommy Atkins.
	Poppies of Flanders.
	Moulin Rouge.
Gainsborough Pictures, Ltd.	.. The Rolling Road.
	Blighty.
	Downhill.
	Easy Virtue.
	Constant Nymph.
	One of the Best.
	The Vortex.
	White Chateau.
Gaumont Co., Ltd.	.. Hindle Wakes.
	Romance of Hinc Moa.
	Roses of Picardy.
	Little " Devil-may-care."
	Robinson Crusoe.
	The Glad Eye.
	Air Drama with Sir Alan Cobham.
	The Arcadians.
	The Dover Patrol.
	Sailors Don't Care.
	The Campbells are Coming.
	Rob Roy.
British Instructional Films, Ltd.	.. Falkland Islands.
	Gallipoli.
	Bagdad to Quetta.
	Buchan Film.
	Shooting Stars.
New Era Productions, Ltd.	.. The Somme.
British Screen Classics, Ltd.	.. The Froth Blowers.

Most of these pictures which have already been released have had remarkably good press notices and some have booked extremely well, both here and in the Dominions, in spite of the very great difficulties attending the distribution of British pictures at the present time.

Amongst the list of producing companies the following are relatively new foundations : —

Britannia Films, Ltd.

Archibald Nettlefold Productions, Ltd.

British National Pictures, Ltd.

British National Pictures, Ltd., which has an important programme for 1927, also includes in its objects the provision of a large studio which will be open to other producing companies on hiring terms. A portion of this studio has already been constructed, and extensions will be made, as the financial position justifies.

Another very important development is foreshadowed in the following statement taken from this morning's *Times* : —

" An amalgamation of British producers, renters, and exhibitors has been brought about by the acquisition by Messrs. Ostrer Brothers, the merchant bankers, of financial control in the Ideal Film Company, the W and F Film Company, and the Biocolor circuit of picture theatres. Messrs. Ostrer already had a controlling interest in the Gaumont Film Company. They intend that all the companies shall continue to be run under separate boards of directors. The Biocolor circuit controls eight cinemas in London, and others in Bradford, Brighton, Bristol, Burslem, Cardiff, Colchester, Glasgow, Grimsby, Hanley, Newport (Mon.), Plymouth, and Stoke. Sir Walter Gibbons recently announced that he had refused the offer of Messrs. Ostrer to purchase the Capitol, in the Haymarket."

I am able to say that other developments, both in the way of extensions of producing units and of the provision of centralised finance are contemplated in the near future. The developments include the extensions of the studios of several existing producing units, some of which are actually in hand.

There is full scope for the British film in this country. There are over 3,500 picture halls in Great Britain, of which about 3,000 are small houses in unfashionable districts. They must have enough pictures to vary their programmes every three days, and they must have these pictures cheap or go out of existence.

Sir Sidney Low has pointed out that British manufacturers must meet this demand, and in quantity as well as in quality, if the foreign import is to be substantially reduced. They must supply a moderate number of first-rate, highly-expensive dramas, and they must also pour out a steady stream of popular cheap films attractive enough to compete with foreign films of the same grade.

TAXATION OF FOREIGN FILMS.

Lord Leigh, speaking on Anglo-American relations, said that one of the greatest obstacles to better relations between the two nations was films

He had never in America met the sort of trashy life portrayed on the films as typical of American social life. These films were used by Bolsheviks as anti-white propaganda in the East. Would not these objectionable pictures be excluded, or at any rate brought within limitations, if adequately taxed?

Approximately six millions sterling goes to America annually from this country on account of the exhibition here of American films, and very little, if any, British income tax is paid on these huge profits.

The American Government levies heavy taxation on all profits made by British and other foreign enterprises in the United States, including the personal and professional earnings of artists, actors, lecturers, etc., who are not permitted to leave the territory of the United States until they have furnished a return and paid the taxes assessed upon them.

A legitimate and considerable source of revenue might be found in following the example of the United States, and taxing profits made by foreigners who are exhibiting American and other foreign films in this country.

Such income tax evasion could be prevented by the imposition of an *ad valorem* duty on the declared value of all imported films, equal to the standard rate of income tax. By this means film importers would be faced with the alternative either of declaring the real value of their imports, or of subsequently paying income tax on their profits, which they now evade by showing such a high charge on their books that little or no profit is apparently made.

A "reel tax" is advocated by Sir Oswald Stoll, who claims that such a tax would raise the standard of the films produced by discouraging films of low merit. In this way, it is argued, the reputation of the British films would be enhanced, and British films would be welcomed throughout the world.

What is needed (says Sir Oswald) is the imposition of an Exhibition Duty upon the exhibition of all non-British films. The duty would be payable by the Exhibitor, and the proceeds, less costs of collection, would be used to promote a constant supply of the best British films. Very much the same measure of protection as is now given to the British Broadcasting Corporation would thus be afforded. The scheme possesses, too, an analogy to the case of the Road Fund.

It is argued—whether correctly or not I am unable to state—that such a tax would in no way affect commercial Treaties, if applied to the films of all countries. It would still leave exhibitors freedom of choice in the selection of their programmes. It would tend to the rapid production of a supply of first-rank British pictures, enabling them not merely to win appreciation at home, but successfully to invade the foreign market. At present the lack of foreign sales is as dangerous as the dominance of non-British films in the domestic market.

By a Reel Tax and the money resulting from it, the Government would be able to ensure an adequate production of certain types of films of educational

value, so much to be desired on Imperial grounds. Moreover, the suggested Tax would do something to counterbalance the dumping of foreign films in this country, with their entire freedom from the burden of any taxation of profits.

British films can only revive when there is an end to the restriction of expenditure upon them to what can merely be got from the present small market. To produce and to spend for a world market is both practicable and profitable. Extravagance may not mean showmanship, but unnecessary restriction is as great an evil. In spite of the great extravagance in America and the quantity of bad films made, the Americans have recognised that the film is a universal medium, and have set out to meet a universal demand.

It is essential to familiarise the Empire with British films. This can be done if renters and distributors have the necessary imagination and enterprise. The creation of a central marketing Board for distributing all British films throughout the Empire would ease matters, and this Board would have agents throughout the Dominions for exchanging films between one part of the Empire and another. Producers, renters and exhibitors could participate in the arrangements for the better marketing of British films throughout the Empire, but without a Reel Tax they cannot thrive on the Empire market only.

There is need for reform in the preparation and editing of British films. Story selection should be the work of literary experts. A scenario should be a matter of long preparation. At present many British films are subtitled with incorrect grammar and spelling. The money spent on the brains of production is often wasted on account of rushed and patched work. A conference on production methods would be of great value to the British film industry. The three essentials for a sound British Film Company are :—

1. Appointment of competent men who can select books and plots for production.
2. Engagement of competent sub-title writers—men of scholastic and literary abilities.
3. Capable studio managers, producers, salesmen and commercial men to look after expenditure.

WHAT THE PUBLIC WANTS.

Mr. Alfred Sutro, writing on what the Film Public wants, advocates the simple and beautiful on the screen instead of abstractions and violence.

The cinema being a new form of expression, a new art must be evolved : the art of writing for the screen. This will come ; it is bound to come. Notwithstanding the business man, it is bound to come. The human brain is very elastic, very ingenious. Man has made use of all that nature has given : he will surely learn to use this fine invention of his own.

The essential mistake of those who control the cinema to-day is that they persuade themselves that they know " what the public wants." They do not.

They think that the bulk of the people care only for stories of love or murder, crime or violence. That is not true.

I maintain that nothing is too good for the people. Plain folk do not care for abstractions; they resent too-conscious efforts at education. But drab lives crave for something of beauty that shall brighten their dullness. The recondite, the pretentious, didactic—these will offend. But the simple and beautiful—and is not the ultimate quality of all great art that it is simple and beautiful?—these will always appeal.

The theatre will surely never be dethroned; the spoken word must reign supreme to the end. But the cinema has its own world to conquer; there is room for both.

Of the value of British films, not only to Great Britain, but to the whole Empire, there can be no two views. Trade to-day follows the film, just as in an earlier generation it followed the flag. Business men tell us that their efforts to sell British goods abroad are being hampered by the lack of British films, both to prepare the way for them and to back up their work. America, on the other hand, tells of trade expansion brought about by the screen, which shows American pictures. Films, too, can and do tighten the sentimental bonds of Empire, and every one which goes out from this country to the Dominions and Colonies should be an ambassador of Imperial goodwill.

DISCUSSION.

THE CHAIRMAN said the audience would agree with him when he said how grateful they were to Sir Arthur for his most interesting and instructive paper. It might be news to some that Sir Arthur was a cinema theatre owner; and he was sure that all felt that if every theatre owner had studied the subject as carefully as Sir Arthur had, and had been animated by the same patriotic motives, there would have been no need for any legislation whatever on the subject. Sir Arthur had referred in a spirit of criticism to the failure of the trade to agree upon any scheme. Personally he took rather a different view from that. He had had some experience of industrial negotiations, and he had never yet dealt with any subject upon which the manufacturers, the wholesale distributors and the retailers in any trade had been in agreement, and he doubted whether such a subject existed. It was remarkable, therefore, that on the very difficult question of British films, the position was that the manufacturers, the distributors and very nearly half of the retailers (or theatre owners) who had expressed any view, were all in agreement upon the scheme which had now been embodied in the Government Bill. That was a very remarkable fact which had been overlooked in the heat of subsequent controversy. The reason for it was fairly obvious, namely, that all sections of the trade were equally in fear of foreign domination. The manufacturer was strangled by it, and both the renter and the theatre owner found themselves drifting into the position when they would only have one source of supply to which to look. They wanted another source to protect them. Therefore they had that community of interest which had been recognised to the very remarkable extent that at least three-fifths of the industry in this country were agreed upon the scheme which was now embodied in the Bill at present before the House of Commons. It

was very easy to attack what was a most important part of that measure, namely, the quota proposal. That was a very novel proposal in the legislation of this country, but there were one or two points which had to be remembered in connection with it. First of all it had not been invented in this country, but in Germany, though upon a slightly different basis. It had been already introduced in Australia and in Austria; and he had seen in the *Times* that morning that Italy was introducing a very similar measure. Therefore a great many different parts of the world thought that that was the only possible solution of the difficulty, and he thought that that was a point to which due weight should be given. The only substantial argument against the quota proposal was that in regard to quality. The fear was expressed that the quota proposal might result in British pictures of indifferent quality being forced upon the exhibitors. That was a kind of statement which it was very difficult to combat except by pointing to the very high quality of British pictures which had been produced during the past two years. A far higher percentage of those pictures were first-class pictures than was the case with the pictures of any other nationality shown in this country. When it was remembered that fully half of the British pictures which had been produced in the past two years had been really first-class pictures, and that out of 600 or 700 American pictures produced in each year and shown here certainly nothing like that percentage could be said to reach that standard, he thought that went a long way towards disposing of the argument. The quota proportion was to begin at $7\frac{1}{2}$ per cent. British producers were already making about $7\frac{1}{2}$ per cent. of the pictures which were shown on the screens in this country, so that it was quite certain that by the time the Bill became law there would be a surplus of British pictures above $7\frac{1}{2}$ per cent., and that surplus, as the quota mounted year after year, should continue; thereby giving a margin for competition and a margin for selection by the theatre owners. Then the point had to be considered as to what safeguards could be introduced. Many important critics had suggested the possibility of some kind of censorship committee. He for one should very gravely distrust any committee which was going to have a power of censorship over quality in any field of artistic production. He had never known such a thing successful in the past. One could imagine that if a theatrical censorship committee of this kind had been in vogue in the late '90's, very few of Mr. Bernard Shaw's plays would ever have seen the stage. A censorship on artistic quality would be an absolutely dead hand upon the industry. As for a censorship of entertainment value, that was the business of the renters and exhibitors, not to mention the manufacturers; and to imagine that any outside committee could say better than those branches of the industry could, what was good entertainment and what was not, was, he thought, absurd. Therefore he did not think any kind of Government censorship could possibly be suggested; such a thing was out of the question. We had to rely upon the low percentage of the quota, upon the high quality of the British pictures now being produced, and upon the fact that this country had always held a foremost place, from the days of Shakespeare down to the days of Dan Leno and Little Tich, in the world of entertainment; and he thought it would continue to hold that place in the film world when it got a fair chance.

The author had referred to a new scheme which he had submitted for consideration. Personally, he did not agree with that scheme; he thought it was quite impracticable. The suggestion was that the foreign films which were detained here in bond, under the provisions for import duties on films, should be released only by order of the Board of Trade or some other Government Department, and that the Board of Trade should ration the market continually so as to leave always a margin

which would have to be supplied by British pictures. He should have thought that Parliament would never sanction any legislation which was going to put into the hands of a Government Department such a complete control of importation. He did not see how any principle could be laid down upon which those pictures were to be released. Parliament would never give that power unless it laid down in the Act very strictly the principles upon which the Government Department concerned was going to carry on that system of gradual rationing; and personally he could not see how any such principle could be laid down. The only thing which could be said would be that the Board of Trade should release those pictures in its absolute discretion, and it was inconceivable to him that Parliament would ever sanction such a measure, or that the British people would ever tolerate it. There was another more serious difficulty than that, which was, that it would not prevent the American industry from starting production over here. It would compel them to come here to produce their own pictures. From some points of view that might be a good thing. It would employ British labour and talent, but it would be under American direction. One would not get out of the necessity of defining a British picture, as Sir Arthur had suggested, because one would be compelled then to do what the Government was proposing in the Bill, namely, to define a British picture, and in some way or other to restrict the distribution and exhibition of pictures other than British pictures whether they were imported or made in this country. One put oneself in a worse position, therefore, for dealing with the difficulty. He thought those objections were absolutely fatal to Sir Arthur's very interesting proposal.

With regard to the power to allow British producing companies to employ a foreign director, he thought Sir Arthur rather exaggerated the dangers in regard to that. Personally he thought the position of a director was not quite so despotic as Sir Arthur seemed to suggest. He believed that in America the studio organisation was now so arranged as to curb the directors' activities; they were now acting under committees, and the director was not so much a despot as he was an official. In any case he thought it might be necessary, during the early stages of the building up of the industry in this country, to be able to call in the assistance of foreign directors, foreign artists, and foreign technicians, provided the matter was kept strictly within limits; and the Bill as it had been introduced, he thought, laid down those limits very strictly. Further, he thought all British producing companies would very much prefer to employ British directors if they could find them, as he thought they would be able to do.

MR. T. C. ELDER (President, Cinematograph Renters Society) said he represented a Society which included foreign as well as British renters. It might be of interest to members to know that that Society had placed itself at the disposal of the President of the Board of Trade throughout the negotiations in connection with the Bill now before Parliament with the object of assisting him to make it a workable measure; and there had been no difficulty whatever with any of the foreign members of the Society in that respect. He felt a little diffident in intervening in a discussion which was rather of a political nature, and which might seem to involve some sort of attack upon the foreign members of his Society. He had been associated with popular and profitable British productions as well as with the marketing of Continental and American productions, and he did not think it was at any time right to get up at a meeting without reminding the audience that as a popular entertainment throughout the world the screen owed an immense debt to American enterprise. He did not desire to go into the details of the Bill now before Parliament, and would therefore confine himself to one or two points which had been mentioned by the

lecturer, and which had to do with the quality or the nature of films. He had to join issue with Sir Arthur when he talked of the simple and beautiful as being likely to make for the entertainment of the millions of this country or of any other country. That was a most dangerous line to take. The invention of films was the greatest invention since printing, and it was beginning rather as printing had begun by circulating stories which were perhaps to some extent low-brow. A great deal of the early printing would to-day be regarded as very low-brow. What the millions of people wanted to-day was undoubtedly a little excitement—stories with “a bit of blood” in them. It was no use blinking one’s eyes to that fact. The lecturer had referred to the decay of thinking; but people did not go to the cinemas to think. Personally he should be very sorry if they did, as it would be a herculean task in these days to keep the people supplied at intervals of three days with something fresh to exercise their intellect upon. It was sufficient for him if he could play upon their emotions. They wanted excitement, and that was another reason why America had a great advantage. He was told the third largest industry in America was films. When he had gone to see a very successful play the other day called “Broadway” (which was entirely an American production), he had heard one of the characters remark that the second largest industry in America was bootlegging. As bootlegging was the second largest industry in that country, he asked the audience to think how romantic the whole circumstances must be, and to consider how much more exciting life must be in America, as compared with what it was in this country. When persons talked about circulating all over the world British ideals, British character and so on, he would ask those persons, as a means of assisting that very desirable object, kindly to be a little more dramatic and exciting in their own lives. The people of this country were comparatively staid and respectable; the tramps in this country did not jump the railway trains; there was no bootlegging in this country and there were no gunmen; in fact, there was a deficiency of romance and drama here. This country was at a very great disadvantage in that respect compared with America. Therefore he begged the audience and all other people to make life in this country a little more dramatic, and then more British films would appear on the international screen.

MR. H. BRUCE WOOLFE said the producers as a whole undoubtedly welcomed the Bill as it was now before Parliament. They felt quite sure they would be able to deliver the goods. The great proportion of the British films which had been shown during the last two years had been of a high standard. With regard to the scheme which had been outlined by the lecturer that evening, personally he could not see how it was going to act. There were at any given moment at least 300 or 400 films waiting for release dates, and he did not quite see how any authority was going to pick out five or six or ten of any of those films in any week and say that those were the films that were to be shown that week, and so on. If that scheme were followed the films would be getting very old by the time the last few were reached. The best thing to do was to leave the Bill as it was, and personally he would be quite prepared to give it every welcome.

CAPT. HARRY LAMBART said he had been the first Britisher who had gone to America in order to become a film producer. He had only intended to remain for three months, but he had stayed there for 17½ years. Since returning from America five years ago he had gone through a great many trials and tribulations in trying to get British finance to assist British films and to put them in the place where they belonged. It was very-galling for a Britisher to be in America and not once be able

to see anything of old England on the American screen. The argument of the American exhibitor was that this country would not send him out anything from England which was as good as he was able to obtain or make in his own country. That might have been so during the period of the War, but since the War England had turned out some first-rate films. The difficulty which had been met with by the Board of Trade had been to get the British producer, renter, and exhibitor, all to agree on one plan. As an old actor and producer on the stage and on the films, he had never yet found that a lot of artistic temperaments had ever been able to agree between themselves; and when Lord Ashfield had suggested last year that there should be a Committee of producers, exhibitors and renters to decide on what pictures should be shown, he had pointed out how utterly impossible it was. A producer would go to the renters and say, "Will you take my film?" If they turned it down, he would then go as a last resource to the tribunal, which was composed of exactly the same men who had turned it down before. The only possible way of getting British films on the British screen and supported by British capital was by adopting a quota scheme, and giving capital a chance of getting a return on its investment in a few months, instead of waiting until its owners were dead and gone.

MR. W. M. BORRADAILE said he had studied the Bill from every point of view, and he thought that in order to meet present circumstances and to get the British industry started, everybody who had the industry at heart should support it.

MR. M. RAYMOND (Ex-Treasurer Cinematograph Exhibitors' Association) said that although there had been a great deal of argument about the state of the British film industry, he had not heard any real remedy suggested, and that was the trouble with the three sections of the trade. He was not in agreement with the Government Bill. The proposed quota would not bring British films. There was no inducement given in the Bill to British capital. There was plenty of capital in this country, but the obstacles were too great, even with a $7\frac{1}{2}$ per cent. rising to a 25 per cent. quota. What was wanted was something to induce constructive work. It was the weakness of the Bill that it did not sufficiently do this. He would go as far as to suggest that the Bill was only introduced in order to placate the Colonial Premiers, and he prophesied its complete breakdown. There would be no capital forthcoming. The Bill was a mixture of sentiment and finance, and those two things could not go together.

MR. JAMES CAWSON said that it was well to bear in mind that six million people in this country were seeing American films every week, whereas they ought to be seeing British films. It seemed to him to be unquestionably desirable that this important matter should be taken in hand in an effective way.

CAPT. J. W. BARBER, C.B.E., said that during the course of his experience he had been impressed with the great importance of the cinema from the point of view of the Empire in bringing about a clearer understanding between the Dominions and the Mother country, especially in connection with India and other large sections of the Empire which did not understand the written word of the English language. The paper that evening had been an indictment of Government inaction in the past. British studios were closed, British artists had gone to America, and there were no schools of technique available in this country. Now there was brought forward a very ill-considered Bill, the object of which was to force on the British public a

scheme which he thought would prove disastrous, unless very drastic amendments were made during the report stage. It was overlooked by the legislators that in the measure one particular section of the industry—namely, the exhibiting side of the industry—was asked to make sacrifices. The producers were made a present of a guarantee of $7\frac{1}{2}$ per cent., and with regard to the renters, the more films they had to rent the more revenue they would obtain. The exhibitor was being compelled to book what was at the present moment an absolutely unknown quantity. He thought the lecturer's scheme which he had mentioned that evening was worse than the Government scheme. He felt that the Government overlooked the very important fact that whilst they could compel, by legislation, an exhibitor to book a British film, nothing on earth would compel a British audience to pay money at the pay-box and patronise that British film if they formed the opinion that that film was not up to the requisite standard. All the exhibitor asked was to be left free to anticipate the demands of his public, which were very readily reflected in the takings at the pay-box. As a constructive contribution to the solution of the problem he would suggest that, in order to foster British films and to get back the technique and the artists who had gone to America, and to put the industry on its feet here, the Government should contribute a certain sum from the Entertainment Tax to support home production. The British Government should be a partner in any sacrifice made for the encouragement of film production.

SIR ARTHUR HOLBROOK, in reply, said he gathered from the tone of the discussion that the opinion was that the Government Bill had been rather hurried. That was not true, because it was quite two years ago when the discussions on the Bill had first been started, since which time Sir Phillip Cunliffe Lister had been in continuous communication with the various branches of the cinema trade in order to find out what was the best line to follow. It could not be said that the legislation had been hurried; he felt rather that it had been too long delayed. Taken altogether, he thought the Bill had met with the approval of those who were interested in the cinema world in this country, because, despite what might be said to the contrary, he was not one of those who thought that anything which Britons did was not so good as what the people of other countries did. He was a strong believer in his own country's capabilities. In literature, in art and in science, despite pessimistic views, Britishers had not been very far behind in the world's history. He attached the greatest importance to our young people being brought up in British traditions. If this were to be no longer the case, the solidarity of our race would be undermined, and it was up to everybody to support any measure which was put forward to prevent that. Personally he thought the Bill was a very bold effort to put matters straight. He was not going to say it was perfect, but he did feel that, having regard to the difficulty which Sir Philip Cunliffe Lister had experienced in getting at the wishes of the people in the trade, it was a very good effort to put the cinema trade of this country on a sound footing and to give British people the chance of seeing something British when they went to the Pictures.

A hearty vote of thanks to Sir Arthur Holbrook for his paper concluded the meeting.

NOTES ON BOOKS

THE DIAMOND TRAIL. By Hugh Pearson. London: H. F. and G. Witherby. 12s. 6d. net.

Eighteen years ago Mr. Pearson read before the Society a paper entitled, "The Diamond Fields of Brazil." He was then recognised as a high authority on the subject, and the years that have elapsed since then have increased his knowledge. The diamonds of Brazil first came into notice in the State of Minas Geraes in 1729, but a more important district is Diamantina where the stones were found on the hillsides, in the swamps, in cracks among the rocks and sometimes they were excavated from a decomposed rock *in situ*. Other important districts are Abaeté, where diamonds of from 52 to 105 carats were common, Bagagem and Agua Suja. Some diamonds have been found in the States of Sao Paulo and Matto Grosso, but to-day the premier position as diamond producer is taken by the State of Bahia. This state is also very rich in carbons, the value of which has increased greatly because of their use for a number of purposes, such as drilling, etc., where extreme hardness is necessary. Mr. Pearson mentions that some years ago a carbon was found which weighed 3,078 carats and was valued at £54,000.

In the volume under review more space is devoted to the story of the author's expedition into the little known interior of Bahia than to the scientific or technical study of diamonds, although there are some interesting accounts of methods of working and of the curious process of "diamond burning," where defective gems are raised to a very high temperature in order to remove flaws. An excellent description is given of the country through which the party made their way, and a sketch map enables the reader to follow their route. Some good character sketches are given of the author's travelling companions and of some of the curious people whom he met on the way.

NEW TYPES OF STREET PAVING IN PARIS.

A type of double pavement has been put into use on several important streets in Paris, according to a report by the United States Trade Commissioner in that city. It consists of a foundation layer of asphalt and a surface layer composed of a mixture of bitumen, rock asphalt and porphyry gravel, to take the place of asphalt, which is dangerously slippery in wet weather. This surface is slightly corrugated, and both layers are applied hot.

Compressed asphalt is being used for new street surfacing in places where vehicular traffic is light or cannot attain high speed. The use of cement concrete is being extended in streets where the traffic is very heavy, and special bricks, in which sandy matter has been mixed to increase their resistance, are being tried. A test section, containing different samples of pavement laid at the expense of the contractors, has been established at the end of the Austerlitz bridge where traffic is heavy.

GENERAL NOTES.

THE GOLDEN VALLEY, HINDHFAD.—This well-known beauty spot, which was given its name of "the Golden Valley" by the late Mr. Grant Allen, and can be seen to full advantage by travellers on the Frensham Road, was lately put up

to auction at Guildford and was only saved, it is understood, from being parcelled out for building purposes by the action of a public-spirited Hindhead resident, who bought the property with a view to gaining time for raising a fund by public subscription for the purchase of the land for the nation. The area is about 96 acres, and the price paid was £5,650. It is stated that the National Trust has been approached on the matter and requested to issue an appeal for funds.

ARCHÆOLOGICAL YEAR BOOK.—A volume which is intended to be an annual world publication is now being prepared by European Books, Ltd., 30, Henrietta Street, W.C.2. The new publication will be entitled, "Vestigia; or, The Year's Archæology in Pictures," and will contain a comprehensive selection of photographic reproductions of discoveries made throughout the world during the year ending 30th June, 1927, and in succeeding years. The publication will be entirely pictorial except for a short general introduction, and it is stated that it will not traverse or interfere with technical reports, text-books and the like. It is understood that the publishers have been granted by the Trustees of the British Museum a sole licence, for a period of five years, to reproduce in this form illustrations in respect of all the expeditions being carried out under the Museum's control, inclusive of those at Ur and Lubantun, and that they are negotiating for similar licences in regard to other important excavations. It is desired to make the new publication a really comprehensive pictorial record of the year's archæological work, and the publishers will be grateful for any assistance which archæologists throughout the world can give them to achieve this object.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

- MONDAY, JUNE 6.** Photographic Convention, at Warwick. 2.30 p.m. Annual General Meeting. Mr. Robert Chalmers, Presidential Address.
- TUESDAY, JUNE 7.** Photographic Convention, at Warwick, (evening). Lecture by Mr. Harold Baker.
- University of London, at King's College, Strand, W.C. 5.30 p.m. Prof. Dr. Rudolf Otto, "The Mysticism of the West compared with the Mysticism of the East." (Lecture I).
- Zoological Society, Regent's Park, N.W. 5.30 p.m. Scientific Business Meeting
- WEDNESDAY, JUNE 8.** University of London, at Birkbeck College, Bream's Buildings, Fetter Lane, E.C. 5.30 p.m. M. le Professeur André Le Breton, "Les Misérables de Victor Hugo" (in French). (Lecture I).
- At King's College, Strand, W.C. 5.30 p.m. Prof. Dr. Rudolf Otto, "The Mysticism of the West compared with the Mysticism of the East." (Lecture II).
- At the School of Oriental Studies, Finsbury Circus, E.C. 12 noon. Mr. T. A. H. Way, "Indian Administrative Law." (Lecture VI).
- At University College, Gower Street, W.C. 5.30 p.m. Prof. Dr. Raymond Pearl, "Experimental Vital Statistics." (Lecture I).
- THURSDAY, JUNE 9.** Historical Society, 22, Russell Square, W.C. 5 p.m. Alexander Prize Essay.
- Photographic Convention, at Warwick (evening). Lecture by Mr. Arthur S. Newman.
- University of London, at Birkbeck College, Bream's Buildings, Fetter Lane, E.C. 5.30 p.m. M. le Professeur André Le Breton, "Les Misérables de Victor Hugo" (in French). (Lecture II).
- At King's College, Strand, W.C. 5.30 p.m. Prof. Dr. Rudolf Otto, "The Mysticism of the West compared with the Mysticism of the East." (Lecture III).
- At University College, Gower Street, W.C. 5.30 p.m. Prof. Dr. Raymond Pearl, "Experimental Vital Statistics." (Lecture II).
- 5.30 p.m. Signor C. Pellizzi "Foscolo e Dante." (in Italian).
- FRIDAY, JUNE 10.** Astronomical Society, Burlington House, W. 5 p.m.
- Geologists' Association, at University College, Gower Street, W.C. 7.30 p.m. Prof. Dr. H. L. Hawkins, "Echinoid Illustrations of some Problems in Evolution."
- Photographic Convention, at Warwick (evening). Lecture by Mr. Alexander Keighley.
- Philological Society, at University College, Gower Street, W.C. 5.30 p.m. Mr. C. T. Onions on N.E.D.
- Physical Society, at the Imperial College of Science, South Kensington, S.W. 5 p.m. (1). Mr. J. H. Awbrey, "The Latent Heat of Evaporation of Sulphur." (2). Mr. H. Lowery, "The Refraction and Dispersion of Carbon Tetrachloride." (3). Mr. P. K. Kichlu, "Regularities in the Spectrum of Ionised Neon." Captain G. J. Finch, "Demonstration of the Schönherr-Hessburgh Nitrogen Fixation Arc."
- Royal Institution, 21, Albemarle Street, W. 9 p.m. Mr. C. Leonard Woolley, "The Excavations at Ur."
- University of London, at the London School of Economics, Houghton Street, Aldwych, W.C. 5 p.m. Mr. Philip Noel Baker, "The Economic Conference held at Geneva, May, 1927." (Lecture II).
- At University College, Gower Street, W.C. 5.30 p.m. Prof. Dr. R. A. S. Macalister, "Celtic Art." (Lecture I).
- 5.30 p.m. Prof. Dr. Raymond Pearl, "Experimental Vital Statistics." (Lecture III).

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*All communications for the Society should be addressed to the Secretary, John Street,
Adelphi, W.C.(2.)*

NOTICES.

FUND FOR THE PRESERVATION OF ANCIENT COTTAGES.

THE PRIME MINISTER'S APPEAL.

The Appeal by the Prime Minister on behalf of the Society's Fund for the Preservation of Ancient Cottages, together with a note by Mr. Thomas Hardy, O.M., has now been issued as an illustrated pamphlet.

Fellows of the Society are urged to apply for copies of the pamphlet to the Secretary ; and it is earnestly hoped that those who appreciate the beauty and interest of our cottage architecture, will do their utmost to assist the Council by distributing copies amongst those of their friends who are likely to support the movement.

PROCEEDINGS OF THE SOCIETY.

INDIAN SECTION.

FRIDAY, APRIL 8TH, 1927.

SIR MICHAEL F. O'DWYER, G.C.I.E., K.C.S.I., formerly Lieutenant Governor of the Punjab, in the Chair.

THE CHAIRMAN said the only qualifications he had for being in the Chair were two ; in the first place he was totally ignorant of Tibet, and, secondly, he had an ardent desire to learn something about it, and this, he fancied, was the position of most of the audience. Tibet, to most people, was a great lone land ; he doubted whether there was any neighbouring country which had been so long on the borders of the British Empire of which so little was known. Britain's relations with Tibet, he believed, dated back to 1775, to the days of Warren Hastings, but until comparatively recently it remained closed, a land of mystery and monasteries. The Tibetans behind the great Wall maintained a splendid isolation, a hermit-like seclusion ; they did not want to have any relations with the outer world,

and resented any attempt of the outer world to penetrate the veil. However, in these days no country could remain entirely aloof from its neighbours, and in one way and another relations, social and economic, had developed with Tibet. They did not at first develop in a very happy way. In 1904 it was necessary to send a military expedition to place British commercial relations upon a sounder basis, and, fortunately, the results of that military expedition, and especially the political work which was done by that great Oriental traveller, Sir Francis Younghusband, so far from antagonising the Tibetans, brought them into relations with this country, which since then had steadily grown closer and more friendly. It was a satisfactory result, and great credit was due to Sir Francis Younghusband. Since that time, with increasing knowledge, our relations with the Tibetans had become better every year, and no one had done more to further that happy result than the lecturer of that afternoon. Sir Charles Bell had been connected with Tibet and the neighbouring States of Bhutan and Sikkim since 1904-5. When the Dalai Lama fled from the Chinese and took refuge in Darjeeling, Sir Charles was attached to him there, and that was the beginning of his friendly personal relations with the Dalai Lama. In 1920, after repeated requests from the Dalai Lama, he stayed with him for a year in Tibet, and therefore had a unique opportunity of studying Tibet at first hand. He had made admirable use of that opportunity and had been good enough that evening to place the knowledge he had acquired at their disposal, and he was sure that everyone was anxious to hear him.

The following paper was then read:—

THE TIBETAN COUNTRYSIDE.

By SIR CHARLES BELL, K.C.I.E., C.M.G.,

Late Political Agent for Tibet, Bhutan, and Sikkim.

Twenty-five years ago we knew very little about Tibet. A few explorers European and American, had visited the country, but were mostly allowed by the Tibetans to travel only in the outlying and sterile districts, and were barred out of the places where people congregate and the national life is found at its fullest. Tibet was aloof and hostile. It was Sir Francis Younghusband who first opened the door for closer intercourse between Britain and Tibet. His masterly achievement in 1904 has made for him a lasting name in British Indian annals. Since 1904, by means which I need not detail here, we have been able still further to establish friendly relations with Tibet. Accordingly the door has been opened wider and wider. A number of us have been through it, so that now Tibet is better known, and, we may hope, better understood.

I have called this paper "The Tibetan Countryside" because there are hardly any towns in Tibet, and I want to speak to you this afternoon about some of the main classes and types—so far as time allows—scattered over that country, whose area is twenty times the size of England, but whose population is less than that of London.

It is usual to divide Tibet, like ancient Gaul, into three parts. In the north is the Chang Tang, the "Northern Plains," a tangled mass of plains and valleys, lying at an elevation of more than 16,000 ft. above sea level, rising several



Mount No-chin Kang-zang.

thousand feet higher in its mountain peaks and ranges. The Chang Tang is studded with lakes, in which the majority of its streams are lost, for they have no outlet. There are no trees, for it is too cold and too high; the grass is scanty, but sufficient to maintain large numbers of wild animals—yaks, asses, sheep, goats, antelopes and wolves. On the fringes herds of yaks and flocks of sheep are tended by the nomads, whose daily allowance of grain is reduced to a quarter of the normal amount, for the barley has to be brought laboriously over the mountains from the lower parts of Tibet; no grain grows in this part of the country. This inhospitable tableland, 1,500 miles from east to west, four or five hundred from north to south, and 16,000 ft. above the sea, is almost uninhabited.

The second natural division is mainly composed of the valley of the Tsang-Po—known in India as the Brahmaputra—and its tributaries. This is, I suppose the highest navigable river in the world, for the handy little Tibetan coracles cross it and go down it for several hundred miles at an altitude of eleven to thirteen thousand feet above the sea.

The third division is eastern Tibet, a country of lower elevations, deep valleys, good grazing and cultivation, and extensive forests. Like many other parts of Tibet, it possesses numerous mineral deposits, but it is not yet known how far these are valuable.

As you listen in the quick-growing Tibetan dawn to the deep notes of the herdsman summoning the yaks down from the mountain slopes, and as you think of the day's march before you across the arid plain, you might be tempted to suppose that this is a land of yellow or slaty hills, with scanty grazing, but practically no land for the plough. Yet this is not so, for you can descend to lower levels, and there you will find broad valleys and plains where more than three-quarters of the soil is regularly and closely cropped.

I want first of all to show you some of the types you would be likely to come across as you travel in Tibet. There are sure to be some traders with their pack animals; mules for the more valuable articles of commerce, yaks or donkeys for ordinary goods. Among these are some of the youngest travellers I ever encountered. They were on their way from Mongolia to Lhasa, a journey of four months. They were strapped into boxes of yak-hide, one box on each side of the yak. The boxes are square, the sides being kept in place by pieces of wood running vertically down the four corners. The babes were placid, and seemed quite happy. You can just see their heads above the boxes.

You always meet a good many priests, too. Many are going on pilgrimages, and a few of these cover every inch of the way by prostrating themselves. Lying on his face, the pilgrim makes a mark with his fingers a little beyond his head. Rising, he brings his feet to this point and again, muttering a prayer, prostrates himself. I once met a Mongolian pilgrim who was travelling from Lhasa to the Yambu Chöten, a sacred Buddhist shrine near Katmandu, a distance of some 700 miles. He had been more than three and a half months

on the road, and would take at least two years to reach the goal of his pilgrimage. Slabs of wood were fastened to his hands to prevent them from being torn to shreds on the stony ground. Pilgrims from Eastern Tibet, seeking the sacred lake of Manasarowar in Western Tibet, have been known to traverse 2,000 miles in this manner, a journey which takes them from seven to ten years.

Another interesting traveller is the itinerant priest. He goes about with a large box containing images, which he shows to the people. He will then recount stories connected with the images, and collect subscriptions. These priests wander from place to place, and give—or should give—their gains to their monastery. They are sent out thus to raise money for church expenses.

A similar calling is that of the monks and nuns whom you sometimes see by the wayside telling stories out of the Tibetan dramas, which they illustrate with pictures. Unfolding one of their picture scrolls, they prop it up against a wall or a rock, and intone the story to which it relates, pointing with a stick to each incident in the picture, as its turn for narration comes. Small knots of people gather round to hear the story, and reward the narrator with their little offerings.

Nuns do their share of travelling as well as priests. You will often see them journeying between their religious and worldly homes, carrying their luggage on their backs, and halting here and there during the nights. Though there are vastly more monks than nuns in Tibet, yet the number of nunneries is not inconsiderable. They are smaller than the large monasteries, and are often situated in secluded valleys, where they are sometimes, unfortunately, despoiled by brigands.

Mendicant priests are a frequent sight. With staff and begging bowl the monk—or nun—passes from village to village, from door to door, especially during autumn, the favourite season for mendicant monks and nuns. The monk is not always begging for himself. A lama has several disciples, and these may beg for him.

Let us turn from the mendicant priest who solicits alms in order that he may carry on his religious life and thus benefit the community—to the ordinary beggar who begs unashamedly for himself. The latter is a real professional, and his trade is hereditary through generation and generation. Tradition denies that this has always been so, for it says that in former days Tibet was so prosperous that there were no beggars, and nobody would accept alms, so that as an outlet for their charity people used to feed the birds!

However that may be, beggars are now ubiquitous throughout the land, though they are mostly seen in the towns, especially Lhasa.

A beggar's form of address is somewhat peculiar. No doubt a wide diversity marks the forms of salutation current in different countries of the world, but few can be more out of the ordinary than that used by the humbler classes in Tibet towards their social superiors. Peasant, shepherd or labourer, when addressing or addressed by one of the gentry, shows his respect by putting

out his tongue at him. A beggar adds the further compliment of putting up his two thumbs, thus signifying that the person addressed is of the first quality, and may be expected to give a present in accordance with his quality.

One meets beggar fiddlers all over the country side. The fiddler is often accompanied by two or three children, who join in the dance and solicit alms to the accompaniment of a plaintive, never-varying whine. Sometimes the instrument played is the clarinet, though the fiddle is the more common.

One of the dangers of travelling in Tibet is the presence of brigands, who infest parts of the country. It is natural that there should be brigands in Tibet. It is a wild country, with vast empty spaces, high mountains and deep ravines. The people are in large measure a nomadic people, and marauding tendencies are ingrained in all nomads who wander over the wide empty spaces. Moreover, the political and social order in Tibet, is several hundred years behind that which now holds in England, and corresponds to a period when highway robbery was rife in this country. It is, however, only fair to add that the present Dalai Lama has greatly reduced the brigandage throughout those parts of Tibet which are under his control. But in those districts of Tibet which the Chinese have annexed, brigandage was, and probably still is rampant, for the Chinese do not keep as good order in Tibet as the Tibetans do themselves.

Many of these robbers have a perfectly respectable side to their lives, however, for they often couple the parts of robber at home and trader abroad. They go on annual trading expeditions to Lhasa and other places, and nobody attempts to interfere with them. The people of Go-Lok, for instance, in the east of Tibet, are notorious brigands, and those of Nyarong scarcely less so. Yet you will find the men and women of both districts as peaceable traders in Lhasa and elsewhere. Occasionally the predatory instinct is too strong for them, and they snatch something off a stall. But this doesn't happen often and many of them make an extremely good thing out of their dual existence.

In 1914 robberies were prevalent in Gyade, a province 150 to 200 miles north-east of Lhasa. The Tibetan Government sent a priest from the Sera Monastery, one of the three great monasteries near Lhasa, as its delegate, to enquire into this brigandage. On arrival the priest demanded ten of the ringleaders, but the robbers came and told him that they would kill him. "That," he said, "will not make this affair smaller; it will make it larger." However, they killed him. The Tibetan Government despatched troops, killed a large number of the marauders and destroyed their strongholds. Or, as the Tibetan idiom expresses it, the Tibetan Government "moulded the robbers' shapes."

There have been instances of monasteries taking to robbery. The important monastery of Cha-treng in south-eastern Tibet, under Chinese rule, used frequently to despatch marauding expeditions. This, however, was actuated largely by the desire to rise against the Chinese rulers. The Dalai Lama

appealed to the monks to return to their monastery—which they obediently did, though flushed with victory, and well placed for plunder. The Dalai Lama himself, when journeying through the land of the Golok brigands, was welcomed everywhere, and received many offerings from them. For it rests largely with him to determine how they shall fare in their next lives. Brigands indeed they are, but brigands after a method that is governed by the needs of this world and the next.

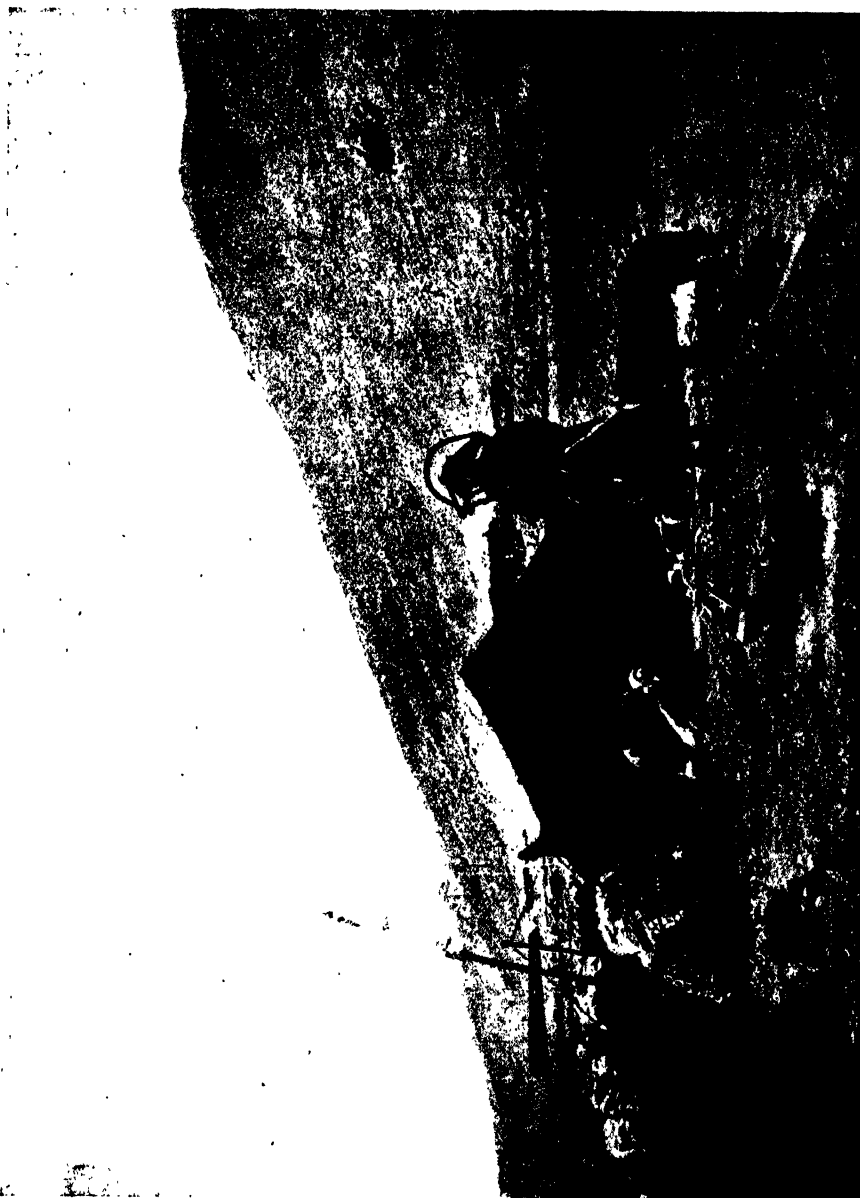
The punishments in Tibet for brigandage are severe. Robbers and other convicts may be found wandering about the market places with heavy irons on their legs, begging for food.



Fettered convict in Gyantse.

Let us now leave the robbers and turn to the shepherds. We may well believe that the Tibetans were originally a nation of graziers, and that in the men and women who graze the flocks and herds over the wide spaces of Tibet are the purest specimens of the race. They live in tents made of yak hair. The specimen on the screen is one of the small type. Many are larger. A tent of average size affords a home to five or six persons.

Let me describe a typical specimen, larger than the one on the screen, one of innumerable others that I met with in Central Tibet. Here and there inside the tent were pails of milk, cream, curds and cream cheeses. There was a basket full of tea leaves which had been used once but were being reserved for a second brew. On a small shrine a butter-lamp was burning in honour of the Buddha, for where will you find the meanest abode



Herdsman's tent at Tuna.

without its shrine? In the middle of the tent a cauldron was simmering over a fire of yak-dung. Outside in the sun the mother sat, weaving the clothes for the men-folk. A couple of Tibetan mastiffs—large, black, long-haired dogs with heavy jaws and bloodshot eyes—were chained to pegs in the ground.

They barked continuously when any stranger approached, and would fly at his throat if they got the chance.

The herdsman shifts his grazing ground at regular intervals to gain fresh grass for the herd. Those in Sikkim often leave their warm, moist valleys in the summer and seek the drier uplands of Tibet. Here they escape from the leeches which swarm unendingly in the wet lands below an elevation of ten thousand feet, and make the life of man and beast one long-drawn misery.

The grass on the Tibetan mountain sides and plains and in many of the valleys looks withered and useless, but the people believe in it. They find the short, dry tufts that grow on their mountains and plains more nourishing for their animals than the long grass near the water, which is itself watery and of inferior nutritive value.

As you pass from the centres of cultivation up the colder valleys to the heights where grazing alone is possible, you see the crops of barley and peas becoming steadily shorter and thinner. You are on the fringe between the peasant and the grazier. One such tract is found at Reting, sixty miles north of Lhasa. Here the inhabitants are known as *Sa-ma-drok*, "Not cultivators, not graziers," that is, a combination of the two; for in this cold country cultivation alone is not sufficient to supply the needs of a household.

As I walked one day up the mountain side above Reting monastery with the "Holder of the Keys," the alert, kindly priest who had charge of the monastic property, I saw incense smoke rising from the farmers' houses below. It was the time for the yaks and other cattle to come home, and so the incense went up as a prayer to the deities to bring them safely down the steep slopes. For, as the Holder of the Keys said, "There is no hope for the herds unless the divine assistance be invoked."

You will sometimes see papers fastened to the yaks as they graze. They are inscribed with prayers addressed to the guardian deity of the yak-owners. For every Tibetan has a guardian deity, not a mere vague idea to comfort wayward or fretful children, but a living personality to help and advise him.

If you come to lower levels in Tibet during the summer you will find the farmer hard at work. His chief crop is barley, which takes the place of wheat with us. He grows also large quantities of peas, and mustard; and for root-crops, radishes and turnips. In the lower elevations, wheat and buckwheat. The peas and buckwheat are consumed by the poor, and the peas are also fed to animals.

The dryness of the land is one of the difficulties that the farmer has to meet. It is so dry that without schemes of irrigation the crops would have no chance.

Ploughing is done by yaks, oxen or dzos, these last being cross-breeds between yaks and ordinary cattle. Sometimes the plough-yaks are gaily decked out for the work. One such pair I saw near Ganden Monastery, some 25 miles from Lhasa. On their heads were red tufts of yak hair, above these tufts of white sheep wool, and on the top were inserted sprays of cocks' feathers. Strings of

cowries, wound round the neck and on the nostrils of the yak, added further to the colour scheme. The right horns carried tufts of yak hair. Behind the plough a man came sowing, and this was noticeable, for sowing is ordinarily a woman's part.

The yak, with its cross-breeds, is the most useful of all animals to the people of Tibet. As a meat food it is consumed more largely than any other, except perhaps mutton. The hair is used for making tents and blankets, as well as ropes, which never seem to break or wear out. The hide furnishes bags, and also coracles, on which the Tibetan relies almost entirely for navigating his rivers. You will sometimes meet a man carrying his own coracle, and with him a sheep carrying a pair of saddle bags in which are his master's food and eating bowl and other needs.

By Europeans, Tibetans are often described as lazy. I think, however, that when I have outlined the length of the working day when the crops are being reaped, you will agree with me that this is far from being the case. I have frequently been staying near the fields at Gyantse when reaping was going on. The peasants and their households rose at one or two o'clock in the morning and went out immediately to the fields. Except for brief meals, they worked unceasingly, till seven at night, when they returned home for a few hours' sleep. And so on, day after day. They used every effort to gather in the crops before the frost came. Often I have heard, between one and two o'clock in the morning, the tinkling of the bells round the donkeys' necks as the patient animals passed my little bungalow, bringing the loads of barley back from the fields. No eight-hour day here, but rather eighteen !

The Tibetans are undoubtedly hard workers on occasions ; but they are also firm believers in the necessity of invoking supernatural aid, if their crops are to do well. When I was returning to Lhasa from the north, I happened upon a service for the crops, at a village called Ya-tsa, near Lhün-trup Dzong. The villagers walked in single file round the village boundaries. One in front carried the banner of the god of the district ; each of those following carried a volume of the Buddhist scriptures. The object of this procession was to ward off frost and hail with a view to the reaping of the crops a few days later. Incidentally, my Tibetan companion did not fail to point out that our meeting with this religious procession was a good omen for our party.

About the time of the New Year there is a curious ceremony, that of the scapegoat who suffers for the sins of the community. The scapegoat, clad in sheep's entrails and with the sheep's heart in his hand, is driven down the hillside where the crops are to be sown, thus, as the Tibetans believe, carrying away all misfortune. Perhaps I ought not to say that he " suffers " for the sins of the community, for he is paid well for the job.

Though his lot may be a hard one according to our standards, the Tibetan does not waste much time in repining. Teams of labourers carrying heavy logs, men and women in the fields, all sing as they work. Cheerfulness is a



Four performers in the Kyormo Lung-nga theatrical troupe. All are men.

dominant Tibetan characteristic, and it often takes the form of song and dance. The theatrical troupes that tour Tibet, especially at certain seasons of the year, are mainly recruited from the peasants. When the tour is finished they return to work in their fields. Meanwhile they have seen a bit of the world outside their village, and have enjoyed it, for the Tibetan loves travelling. He has the instinct of the nomad, and his life as a husbandman is humdrum.

He has also the instinct of the trader. Though there is a regular trading class, still almost all the people from time to time engage in commerce. During the height of winter, when ice and snow suspend agricultural operations, many of the peasants go northwards to the salt-producing districts, and increase their farm earnings by retailing the salt in other places.

An immense import trade in tea is carried on. The tea arrives in bricks from China, and is chiefly distributed throughout Tibet from Tachienlu, the centre of the tea trade.

Tea is the great stand-by of the Tibetan. No Tibetan drinks less than fifteen or twenty cups a day, and some even seventy or eighty. To the tea butter, as well as soda, is added, so that a scum forms on the surface. This you blow aside before drinking. Europeans almost invariably dislike this tea, but it is not unwholesome. The cauldrons shewn on the screen may give you some idea of the scale of Tibetan tea consumption. Tea was boiled in them and served out to the monks during the Great Prayer Festival at Lhasa.

By far the largest export from Tibet is in wool, and of the animals which travel down through Sikkim to India, at least three-quarters are laden with wool. And very useful it is when the muleteers halt for the afternoon and night on the windy plain. The drums of wool are built into a wall, along three sides of a square, to keep the wind out. At one of the corners the watch-dogs are tethered. As you approach an encampment, the dog will dart out from within. So you must allow for the length of the chain; otherwise you will find his teeth in your throat. The drivers stay contentedly inside the square under the open sky. They sit and talk and cook their food, and when darkness falls they snuggle under their blankets. The starry heavens are above them, the temperature twenty degrees below zero; but they sleep well, and are up at four or five o'clock next morning.

The large monasteries also trade widely. I found an example of this at Reting, one of the foremost monasteries in Tibet, where I spent a few days in 1921. It is connected with the Shi-de Monastery in Lhasa, which was burnt and looted by the Chinese in 1911 and 1912. So the "Holder of the Keys," to whom I referred a little time ago, was sent to Sining to gain profit by trade in order to help in repairing the ravages. He borrowed money from the Dalai Lama, and was absent five years on his mission, spending over two years of that time in Urga. He bought incense-sticks, drugs, woollen cloth, silks and a

variety of other things. With the profits on these, fresh images were made for Shi-de and a part of its restoration work was also paid for. The "Holder of the Keys" is the head of the administrative side of the monastery, the Labrang.

The story attaching to the foundation of Reting is rather curious. The monastery, though it lies at an elevation of 14,000 ft., which is well above the tree line in Tibet, is surrounded by a wood of juniper trees which grow to a height of fifty or sixty feet, and climb the mountain side to an elevation of over 15,000 feet. Their height and thickness and the large number of them excite wonder and admiration among the Tibetans who come here, and I have myself never seen juniper trees of such size growing at anything like so high an elevation. Two of the priests in charge of the monastery told me that King Song-tsen Gam-po, a famous Tibetan king, who lived in the seventh century of our era, visited this place. Cutting off his hair, he strewed it on the ground and prayed that timber might be provided for building a monastery there. In answer to his petition these trees sprouted from his hair; and some three hundred years later the monastery was built by a disciple of Atisha, the celebrated Indian Buddhist who, in the eleventh century, quitted the great monastery of Nalanda to shed the light of his learning on Tibet.

Now in the monastery, in a small chapel of its own, is kept a certain image which was brought from Li Yul by Atisha. It was given by him to the disciple who founded Reting. This image is called Cho, like the two at Lhasa. A Cho is an image of special sanctity, for it is one that is believed to have been made of the Buddha during his life time. So imitation Cho are installed when it seems necessary to safeguard the real Cho. We being of a different religion, it was not thought fitting that the true Cho should be set up for us to see. So three or four days before our arrival the imitation Cho was placed in position. But sounds of rattling and tapping came from the Chapel, and later on a fracas occurred among the monks. These ill-omened signs were not to be disregarded; so the Oracle was consulted. Two small pieces of paper were put into balls of barley dough, one in each. One paper asked whether the real, the other whether the imitation Cho should be placed in the Chapel. The balls were put into a cup and shaken, and the paper which came out was found to be that which asked for the genuine Cho. Still doubtful, the monks resorted again to the Oracle. On one paper was written, "Is Minister Bell's fortune such that, though of an alien religion, he should meet the real Cho?" On the other paper, words in an opposite sense. The first paper came out, and it was thus held by the monastery that I was destined by my *karma* to see the real Cho, which was accordingly installed in position.

When I left Reting I was offered the stag and hind, which you see on the screen, as a parting present, but I thought it better not to accept them. They are *Cervus Thoroldi*; they had been captured in the neighbourhood, and kept as pets at the monastery. I am not sure whether any other white man has seen this particular kind of deer alive at close quarters.

I have told you a little about types of people that you come across in the Tibetan countryside—priests and nuns and pilgrims, beggars and robbers, herdsmen, peasants and merchants. These, with the landed gentry, make up the Tibetan nation, and I will say something about the landowners now.

Tibetan society falls into two main classes, the landed gentry on the one side, the peasantry and shepherds on the other. The trading community stands between the two, forming a middle class with middle class aims, but they have, so far, little power. There is no strong middle class.

As befits a country still in the feudal stage, the nobles of Tibet exercise great power and influence. With the priests they share the higher posts in the administration; like the monasteries, they own large landed estates. Over their tenantry they exercise magisterial powers; and in districts far from Lhasa almost power of life and death.

There are three possible sources from which a Tibetan nobleman can trace his descent. It may be that some ancestor of his was ennobled for good work done for the country. Or he may be descended from a family in which a Dalai Lama or a Tashi Lama re-incarnated, in which case the whole family automatically acquires noble rank. Or he may be a direct descendant of the early monarchs of Tibet; and this is the oldest and smallest section of the aristocracy.

Throughout the greater part of Tibet there are families of noble stock. In the Tsang province are eight or nine who stand above the others. But the Tibetan aristocracy outside the central province, being as it were localised, has not quite the wide influence of the families from Lhasa, who are employed in multifarious posts, gaining experience and influence from one end of the country to the other.

The houses of the nobility are imposing edifices, usually built—at any rate in Central Tibet—around a rectangular courtyard. You enter by a solid wooden gate. On three sides are stables and storehouses; on the fourth, opposite the gate, is the mansion itself, one or two stories higher than the other three sides, and sometimes as much as five storeys in height. A building on this plan offers the greatest protection against the blustering gales of the Tibetan tablelands, and groups the entire household, family, servants and cattle, within its patriarchal embrace.

It is considered unlucky to rebuild a house. Large portions of the Lha-lu mansion, on the outskirts of Lhasa, were rebuilt some years ago, and misfortunes soon after came upon the family. These misfortunes were attributed to the rebuilding, in accordance with the Tibetan saying,

“ If a house be rebuilt,
Then the pillar will fall,”

which, in plain language, means that a member of the family will die.

Most of the noble families are rich, but not all. Some have lost their wealth long ago, but as long as the unbroken male descent continues, they cannot lose

their social position. A family may have a good *rik*, though poor and without a high official position. And, having it, the sons and daughters will eat, drink and marry with the most exalted in the land. The Lhasa families having the best *rik* are Rakashar and Karap Shenka. Here you see a picture of some members of the Rakashar family, who trace back their descent for fourteen centuries.

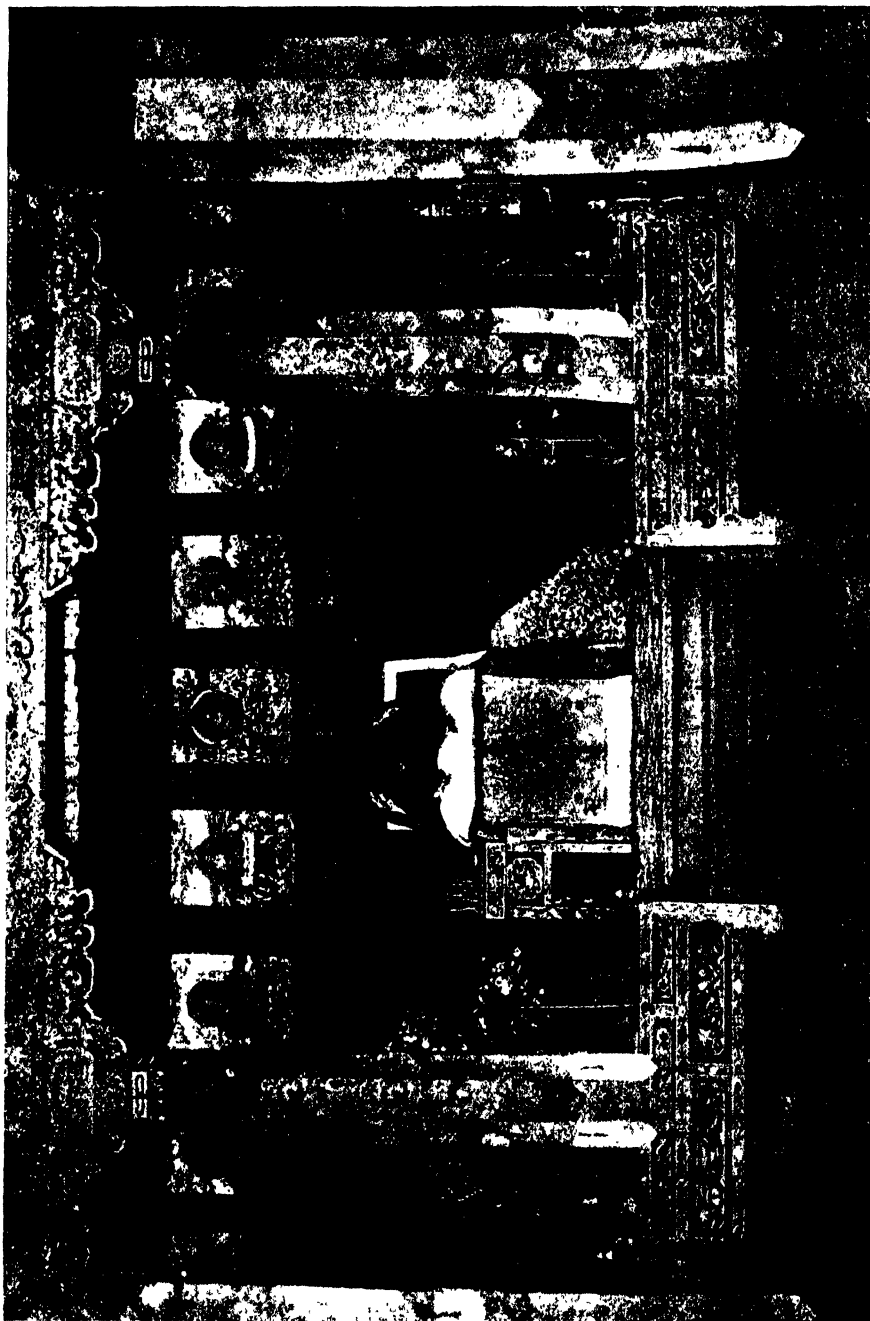
Before concluding let me say a few words about the Tibetan women. They hold, as is generally agreed by Chinese and Japanese, Europeans and Americans, a high position. There is no *purda*. They talk and walk and have their being among their menfolk. In the home the wife has a considerable say in all matters of importance, and has entire charge of the indoor management. Government officials habitually consult their wives on official business. And from early times parts of Tibet have been governed by women.



The richest merchant in Gyantse sitting at her stall in the market.

In ordinary homes the women help with the farm work, milking cows and making butter. They also take an active part in trade. Here we have a picture of a woman who was reputed to be the richest merchant in Gyantse. She is sitting at her stall in the market, looking after the pennies as well as the pounds.

Apart from the one great woman incarnation, Dorje Pamo, women are not held of so much account in the religious life of the State. This is noticeable when the Dalai Lama blesses suppliants in accordance with their rank. He places both hands on the heads of those of the highest rank, both lay and eccle-



The Dalai Lama on his throne in Norbu Linka (the "Jewel Park," his country residence) as when blessing pilgrims.

siastical. With one hand he blesses all ecclesiastical and civil officials, and all monks, even the lowest. The heads of all others the Dalai Lama touches with a tassel held in his hand ; and in this last class are included all the women of Tibet, excepting only Dorje Pamo.

The marriage customs would take too long to describe in detail. All three kinds are found, monogamy, polyandry and polygamy. Monogamy is most frequent, though polyandry is fairly common. One woman marries the brothers in a family ; if she marries the eldest, she marries all, but if she marries a younger brother, she takes as additional husbands only those who are younger than this one.

Polyandry is often found both among the herdsmen and the peasantry. Reasons for its prevalence among the herdsmen are that men are needed to go to the lower countries to buy grain, as well as to go to the higher lands, the desolate uplands where the salt is found, in order to procure salt for consumption and sale. The herdsmen do not eat much grain, but a little they must have. And no doubt in the nomad's wandering life women and children are somewhat at a disadvantage.

Well, Ladies and Gentlemen, Tibet and its people differ so fundamentally from Britain and Europe and India, that much more might be said, were there time to say it. But the time at my disposal has sufficed only to probe into the subject.

I have said nothing of Lhasa, as it hardly comes within the scope of this paper, and it is no longer the "Secret City" of our childhood. I think it was Mr. Aldous Huxley, voicing the younger generation, who said that we might soon expect to find a cinema operator at its every street corner. That, I am thankful to say, is an exaggeration at the moment. But there is no doubt that during the last twenty years we have made great strides in our knowledge and understanding of Lhasa and of Tibet as a whole.

I think, however, you will agree with me that no account of Tibet can be complete without some mention of that lonely figure, who is at once the god and the king of Tibet, the figure to whom all these Tibetans, priests, noblemen, peasants, shepherds, merchants, beggars—yes, even the robbers—turn. So in conclusion I am going to show you two more slides. The first is the Potala at Lhasa, the palace in which the Dalai Lama lives, nine hundred feet in length and higher than the cross of St. Paul's Cathedral. This great stone building is of a mighty massiveness, simple but majestic—one of the marvels of Asia.

The last picture is of the Dalai Lama himself, seated, ready to bless his people. It was my good fortune to come into such long and close relationship with him, that when I left Lhasa five and a half years ago, I felt there were few Orientals whom I knew so well as this secluded and mysterious personage, who dominates the lives of the Tibetan people.

DISCUSSION.

CAPT. F. KINGDON WARD said it had been a great pleasure to everyone to make such an interesting journey through Tibet in company with Sir Charles Bell, who was not only a great Tibetan traveller, but a very fine Tibetan scholar. There were one or two things he should like to mention about the country, and the first was that mountain people were proverbially hospitable, and that was very true of the Tibetans, who were also extremely courteous. When he was in Tibet a few years ago the head men of the villages, and even monks from monasteries, knowing that he and his colleagues were visiting a certain place, would sometimes ride out several miles to meet them, bringing flagons of country-brewed ale or churns of tea and give them a meal, and then escort them to their destination. At the end of a day's march, on arriving at any village, the people would be always very delighted to put them up; but he would give a warning, that nobody should ever arrive at a Tibetan farmhouse after dark. The houses were often extremely isolated, and after dark the people were rather suspicious. On one occasion he arrived about eight or nine o'clock and knocked at the door, but nothing happened for some time except that dogs barked ferociously in the courtyard, and somebody with a gun put out his head from the window. On another occasion they were determined to spend a night at a village, and he climbed over a wall and dropped into the courtyard without locating the dog, and nearly jumped upon him, but luckily he was chained up. The Tibetans were not only courteous and friendly, but they were very honest. At one time, when he was travelling, one of the bags broke and a tin of tea was lost, and tea being scarce at that time, he sent a man back to look for it, but he could not find it. Three months later, passing that way again, no sooner had they arrived at the house than somebody brought the tin of tea and said that a casual traveller had picked it up on the road and handed it over to the villagers until somebody claimed it. It was kept by the people in the house for three months. The lecturer had said something about the crops in Tibet. In the South-Eastern Provinces and along the Burma and Assam frontiers, a great deal of rice was grown. It was not typical Tibetan country, the average altitude being only from 6,000 to 7,000 feet. Maize was also grown. The people who lived in that district spoke a rather different dialect from the Lhasa Tibetans. He was there only a few months ago and was able to purchase quite a lot of rice. The well-to-do Tibetans in the interior were turning more and more to rice diet, all the rice having to be imported into the Lhasa country from the sub-tropical countries or India, and he believed the trade with India in rice was increasing very considerably. The sub-tropical provinces of Tibet in the South-Eastern corner were so abhorred by the average Tibetans that in the old days it was regarded rather as a place to which to send convicts for penal servitude, and probably a large part of the population of that Province had descended from convict ancestors. He had found when travelling on the plateau in the very coldest time of the year that the Tibetan caravans would not often travel by day. They camped by day and travelled by night. The gales started regularly about ten o'clock in the morning and blew with fury all through the day, but ceased suddenly at nightfall. Sometimes he and his colleagues were torn between the desire to stay in their beds and the anxiety to start before the gale began to blow, but generally they started about eight or nine in the morning and were caught in the thick of the gale later on. At night the air was perfectly still, and the cold was not felt at all. He had been through the village where the present Dalai Lama was born, and had found that a temple was built on the site of the house in which he was born, and that some of his family were still there, one being his sister. They

called on the lady, imagining they would find some regal potentate more or less seated on a throne, but they found her out watering the ponies, and she was just a little rosy-cheeked country girl. The marriage ceremonies of Tibet were also of an interesting nature. Some years ago in Eastern Tibet they had a variety of customs. He once met a man who had been taken by one of the young ladies in a troupe of minstrels and spent the afternoon with them carousing, and, not being well up in native customs, he had the misfortune accidentally to marry one of the girls, and had a great difficulty afterwards in getting rid of her. When travelling in a foreign country it was best, not only to know the language, but to be acquainted with the customs of the country.

MR. GEORGE SETON said he happened to be interested in tea in India, and should like to know whether the lecturer could say whether the Tibetans ate the tea or drank an infusion. He should also like to know whether there were any indications of the beginning of a trade with Tibet in Indian tea.

MR. T. W. HODGKINSON said with regard to the probability of tea finding its way into Tibet that years ago it was hoped that a considerable amount of Kumaun tea would go over the passes, but unfortunately that had not been realised. He had no actual knowledge of Tibet, but knew the country for twenty or thirty miles on the Indian side of the passes, and had derived very great pleasure from the very lucid manner in which the lecturer had described the countryside of Tibet. He had travelled with a large number of Tibetans at a time and had been struck by their solid good humour on almost all occasions, under considerable trial, and he had always had a very great regard for them.

SIR CHARLES BELL, in reply, said that with regard to the question as to whether the Tibetans ate the tea leaves, he had seen it stated in books that they did so, but as far as his experience went he had not seen it. In regard to the question as to whether there was a future for Indian tea or Kumaun tea in Tibet, the great difficulty in that matter was that Indian tea could not be prepared in the way that Tibetans prepared their own tea. If Indian tea was boiled with water to the extent that the Tibetan tea was boiled, it became extremely bitter and very indigestible, and Tibetans had often complained of the indigestibility of the Indian tea when treated in the way they treated their own, a method to which they were wedded, and they would not be prepared to adopt Indian tea. So much was that so, that even in Darjeeling and places entirely under British Indian rule, it would be found that most of the Tibetans were getting their tea laboriously at from two to four times the cost right away from Western China. They might be only coolies, but they would have that tea to prepare in their own way. With regard to the good humour of the Tibetans, he entirely agreed that they exhibited the greatest good humour under all circumstances, and that was one of their dominant characteristics.

THE CHAIRMAN said that everyone had derived much instruction and enlightenment from the admirable lecture and the beautiful slides that had been shown by the lecturer, and the interesting supplemental remarks made by Captain Kingdon Ward. Everybody in the room knew more about the lone land now. Some people might wonder why there was the extraordinary desire to penetrate the mystery of Tibet; once it was penetrated and a traveller had seen its bleak hills and valleys and steppes, one wondered how existence could be carried on under those conditions. The Tibetans seemed to be able to do so, and they lived very

cheery, breezy lives amongst all their difficult surroundings. They must obviously be an extraordinarily hardy race and have organised their habits of life wonderfully well. There were many interesting points in the lecture which he had not sufficient knowledge to touch upon, but he thought their method of averting evil by means of the scapegoat was extremely ingenious; some might wish it were possible to adopt it in this country, because if that easy method of ridding ourselves of evil things and evil persons could be adopted, probably it would be found that a great many people would qualify for the position of scapegoat, especially if accompanied, as in Tibet, by high remuneration! Another interesting point was the position of women, and he had been very glad to hear that their position in Tibet was so free, as indeed it was in every mountainous country and in nomadic life. The position of women in Tibet seemed to be the reverse of that of a sailor; a sailor, it was said, had a wife in every port, but it would appear that the Tibetan woman sometimes had a husband in every town. Those who had had the good fortune to meet Tibetans could not but admire their unvarying cheerfulness and good humour. Fourteen years ago, when in Simla, Sir Charles Bell brought the Tibetan delegate who was conferring with the Chinese and British delegates in settling differences between China and Tibet to see him. The delegate was a cultured man with charming manners. On taking him round a large drawing-room, which contained a full-length mirror, which the Tibetan had never seen before, he expressed great delight at seeing himself at full length, and called up all his suite, one after the other, to present themselves before the mirror and bow. On taking him into the conservatory he almost worshipped the flowers. He did not wonder that the Tibetans had endeavoured to keep themselves aloof from the outer world. After all, looking at the map and seeing how they were surrounded by three great empires—Russia on the north-west; China on the south-east, and British India on the south—naturally those hardy free-born highlanders did not want to be interfered with by their powerful neighbours. He thought Great Britain had very wisely limited herself in dealing with Tibet to the development of trade relations and to the endeavour to secure Tibetans from any undue interference, not only from Britain herself, but also from her other powerful neighbours. That was one reason why Great Britain could get on so well with them. The lecturer had interpreted the mentality of the Tibetans in a way that no European had ever done. One example of his understanding of Tibetans and of the Tibetans' understanding of him was, as he had said, that he was able to inspire a Tibetan oracle. If his knowledge of, and prestige in, Tibet were so great that he was able to "work the oracle" in that renowned monastery, no wonder he was an extremely successful representative of the British Government with the Dalai Lama. He asked those present to accord the lecturer a hearty vote of thanks for the immense amount of delightful instruction he had given them.

The motion having been carried unanimously, the meeting terminated.

NOTES ON BOOKS.

PHOTOGRAPHY: ITS PRINCIPLES AND PRACTICE. By C. B. Neblette, A.R.P.S.
London: Chapman & Hall, Ltd. 30s. net.

This large volume represents an American attempt to meet the need for a students' text-book dealing with the scientific basis as well as the practice of photography.

The author's claim that this need exists will be readily conceded, since the existing text-book literature is mainly very poor. The whole modern theory of photographic exposure, development and printing rests on the secure foundation provided nearly forty years ago by the researches of Hurter and Driffield, and in the absence of such foundation the subject is a mere jumble of incomprehensibility; yet it is rare to find a text-book in which this basis is definitely adopted, though one or two honourable exceptions might be named.

The field, then, was undoubtedly open; and in many ways Mr. Neblette has made good use of his opportunity, presenting to the reader a great mass of information which cannot fail to be of interest and utility. A text-book on such lines as this, however, cannot be judged merely as a compilation; and in the more expository portions of the work we cannot avoid becoming aware of serious deficiencies.

Most teachers would probably agree that good criteria of an author's success in this field will be provided by his handling of two difficult subjects: the spherical aberration of lenses, and the sensitometry of emulsions. For the former subject, two quotations will suffice. On page 89 the author states: "In spherical aberration we are concerned only with the rays parallel to the axis; when oblique rays are considered the aberration is known as coma;" and again, on page 92: "Coma, or zonal aberration, is the name applied to the spherical aberration of the oblique rays of light on passing through the lens. With spherical aberration proper we are concerned with direct pencils of light parallel to the axis . . ."

This kind of thing is most deplorable, and not merely from the aspect of terminology. Spherical aberration of the axial or symmetrical type—that which the author calls "spherical aberration proper"—does not affect axial pencils alone. Surely a most limited practical experience of lens systems—even such, for example, as is afforded by adjusting the tube-length of a microscope—would suffice to show that axial spherical aberration appears in all parts of the field simultaneously; and surely even common sense might indicate that an aberration which influenced only the *axial point* of a field would be negligible, or even imperceptible. Possibly Mr. Neblette has been misled by the name, but of course axial spherical aberration is so called, not because it affects axial pencils only, but because it is the only aberration that does affect axial pencils.

The truth is that this aberration affects oblique pencils in (approximately) the same degree as axial ones, and that coma is a quite unrelated oblique unsymmetrical aberration; often the two co-exist in the same optical system, but either can be corrected separately. The expression "zonal aberration" has no particular connection with coma, and still less is it synonymous with that term; it is used, in a manner too complex for discussion here, to denote the residual left outstanding when a primary aberration has been balanced as favourably as possible against a secondary of opposite sign. Finally, even if we were to omit all consideration of oblique symmetrical aberration, it would still be inadmissible to assert that any oblique aberration must be coma, because we must take into account the third anti-stigmatic aberration, namely astigmatism.

In the chapter on sensitometry we encounter much the same kind of thing. Thus on page 241: "A negative is said to be a perfect representation of the subject when the opacities of its gradations are proportional to those parts of the subject which they represent. It must be distinctly understood that this does not imply that the opacities must be in direct proportion to the light intensities of the subject in order that the reproduction be correct; it is *proportional* and not *direct proportionality* which is necessary." We have here three consecutive statements, of which the second is a direct contradiction of the first; while as to the third, the

reviewer must confess that he is unable to assign to it any meaning whatever. Nor is the situation eased by an illustrative table which is immediately subjoined, since for each negative in that table the stated opacities *are* in direct proportion to the stated light intensities of the subject.

After all, the science of mathematics provides a recognized apparatus of convention and symbol by the use of which simple numerical relationships can be definitely described. It may no doubt be pedantic on many occasions to make use of formal mathematical language, but the present occasion is not in that category. Unfortunately, when the author, feeling perhaps that his treatment so far has not been very happy, proceeds on page 243 to put his idea into formal mathematical shape, he falls into an absurdity: “. . . and the law which alone would produce absolutely true tones in photography can be expressed by saying that the quantity of silver reduced on the negative, or the density, is proportional to the logarithm of the light intensity.” To appreciate the falsity of this statement, we need only consider that whenever the light intensity, expressed in no matter what units, has a fractional value, its logarithm must of necessity have a *negative* value; and therefore, if the above statement holds, the density also must have a negative value, which is absurd. Needless to remark, the photographic expert will on this occasion know what the author is trying to say, which is something quite different; but what is the student to make of it?

It is a relief to turn from these tangled paths to what may be termed the more compilatory portion of the book, which contains much that may be praised unreservedly. The opening chapter on the development of photography is of unusual interest, and there is later a most excellent description of the characteristics of a very large number of photographic objectives, of both current and obsolete types; but perhaps the most marked feature is the vast amount of information relating to printing processes of all kinds.

THE MANUFACTURE OF CHINA TEA.

Two impressions are left upon the mind of even the most casual visitor to the Orient. One is the charming manners of the Chinese gentlemen—the essence of cultured tradition down through the centuries; the other is the haunting fragrance of a cup of Chinese tea. As the Chinese were the first to discover the value of tea as a beverage it is natural to suppose that of all the people who drink tea the Chinese should know more than any other concerning the methods of preparation. The Chinese place the tea leaves in large cups not unlike bouillon cups without handles, and the cups are then filled with boiling water and covered. The covers resemble inverted saucers and are used to strain off the tea, which is drunk without the addition of sugar or milk. The covered cup is raised to the mouth, and, with the fingers of the hand holding the cup, the lid is moved with the forefinger just enough to permit the liquid to flow into the mouth as the cup is tilted.

The best Chinese teas are grown on terraced hillsides. The cultivation of tea is a side-line, rice and other crops receiving the first attention of the Chinese farmer and his family.

From a recent report by the United States Consul at Hankow it appears that the manufacture of tea according to native methods is much the same as it has been for hundreds of years. There are five distinct processes in tea manufacture—withering, rolling, fermenting, firing and sifting.

As the name signifies, the withering process consists in drying the leaf, which

is usually accomplished by simply laying the plucked leaves out in the sunshine on straw mats and occasionally turning them so that they dry evenly. Under this treatment the tea gradually darkens in colour. When a rich green state is reached tests are made to see that the drying is not carried to a point where the leaves become brittle. In unfavourable weather the withering is accomplished in artificially heated rooms, care being taken to see that all stale air and gases are promptly removed from the drying chamber.

The second process, known as rolling, is really a further stage in the withering process. In China this is done by hand, the product being placed on wicker or bamboo trays and rolled backward and forward with the palms of the hands for a period ranging from 30 minutes to an hour. This is to break the cells and to express sap and moisture.

The third, or fermentation process, determines whether the product is to become black or green tea. At this state in the preparation the leaves are placed on some flat surface and covered with a damp cloth. The process is sometimes hurried in another way, by the use of covered wicker baskets under which a slow fire is built. This treatment, which usually requires from 2 to 6 hours (depending on the weather and the methods used) is terminated when the leaf takes on a copperish tinge. It is called Hung Cha, or red tea of the Chinese. If green tea is desired, the fermentation is either done away with entirely or checked before any change in the colour of the leaf occurs.

The most important stage is that of firing, for the flavour of the product is determined in this process. The methods employed are very crude. A basket, measuring about 30 inches in diameter and 3 feet in height, open at both ends, and having a light bamboo bottom placed about half way up, is the most common receptacle used for firing. The tea leaves are placed in the upper half and the basket is then placed over a charcoal fire. In this manner all remaining moisture is driven off and the desired flavour given to the tea.

The fifth and last process is sifting and grading. The sifting is accomplished by means of a number of sieves, each smaller in mesh than the preceding one. A careful grading of the tea is made after each sifting.

The high-grade Chinese teas are not artificially scented, the real Chinese connoisseur of tea taking delight in the natural aroma. All except the finest Chinese teas must be blended in order to give sufficient strength, and those high-grade Chinese teas are too expensive for the ordinary buyer.

The high-grade black tea manufactured in China is confined to the fine Souchongs, Keemuns, and Ichangs, the latter being produced in the province of Hupeh. These teas sell on their merits, and the buyers are usually a select clientèle willing and able to pay the price. As for the rest of the black teas manufactured in China, it is solely a question of price. If they can be marketed under the prevailing rate for India, Ceylon, and Java teas, then they can be disposed of; otherwise, they are a drug on the market.

Scented Chinese teas have recently become popular with foreigners. Scented tea comes from Foochow and is prepared by heating certain kinds of flower petals with tea leaves. In some instances the flower petals are left in the tea, while in the preparation of other varieties the process consists in sprinkling a layer of fresh white jasmine blossoms over a layer of tea, and repeating the process until the basket is filled. The receptacle is then placed aside until the perfume has thoroughly permeated the tea leaves, which are afterwards separated from the petals. This mingling of the tea leaves and the flowers is repeated until the desired aroma is attained. Then the tea is ready for packing.

The flowers commonly used by the Foochow tea manufacturers are the "chu lan" or white jasmine, "hsiu-kwei," and the "yu lan," a species of magnolia. The jasmine is the most expensive flower used by the Foochow manufacturers. It costs the tea men from £4 to £8 a picul (133½ pounds). Scented teas are very popular in China and are always made of high-grade tea leaves. Black tea is scented for the American market.

Brick tea is exported to Russia in large quantities, and is also consumed in large quantities in Mongolia, Tibet, and Chinese Turkestan. The Chinese manufacture brick tea principally for the trade of these regions. From Kalgan, Paotow, and Kweihua the tea bricks are distributed all over the Central Asian plateau by camel trains in exchange for wool, furs, and skins.

The process by which brick tea is manufactured is exceedingly simple. Lead moulds, made up in elaborate designs, are placed in the hydraulic presses. A steaming layer of high-grade tea is put into the mould, followed by a thicker layer of coarser grade, and capped by a thin layer of high-grade leaves. The cover of the mould is put in place and the mass is subjected to high pressure. The moulds are removed from the press and the bricks are allowed to cool, the time ranging from a few hours to weeks. The finished product is packed in bamboo baskets ready for distribution, 80 bricks to a basket, with a net weight of 200 pounds. This is typical of the process in all the foreign factories in Hankow. Tea dust is imported into Hankow from Ceylon, Java and India, to be mixed with locally grown tea leaf and fannings.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, JUNE 13. .Actuaries, Institute of, Staple Inn Hall, Holborn, W.C. 5 p.m. Annual General Meeting.

Geographical Society, at 135, New Bond Street, W. 8.30 p.m. Dr. H. E. Hurst, "The Hydrology of the Nile."

Victoria Institute, at the Central Hall, Westminster, S.W. 4.30 p.m. Dr. Alfred T. Schofield, "Time and Eternity."

University of London, at the London School of Economics, Houghton Street, Aldwych, W.C. 5 p.m. Prof. E. R. A. Seligman, "The Hire Purchase System." At University College, Gower Street, W.C. 5.30 p.m. Prof. Dr. R. A. S. Macalister, "Celtic Art." (Lecture II).

TUESDAY, JUNE 14. .Asiatic Society, at the Royal Society of Arts, Adelphi, W.C. 4 p.m.

Colonial Institute, at the Hotel Victoria, Northumberland Avenue, W.C. 8.30 p.m.

Illuminating Engineering Society, at the Stationers' Hall, E.C., 6 p.m. Mr. H. C. Weston, "The Relation between Illumination and Fine Work with special reference to Lighting and Printing Works."

Quekett Microscopical Club, 11, Chandos Street, Cavendish Square, W. 7.30 p.m. Prof. H. Graham Cannon, "The Feeding Mechanisms of Crustacea."

Röntgen Society, at 1, Wimpole Street, W. 8.30 p.m. Prof. Sir J. J. Thomson, "Structure of the Atom and Radiation." (Silvanus Thompson Memorial Lecture).

WEDNESDAY, JUNE 15. .Archaeological Institute, 10, Bloomsbury Square, W.C. 5 p.m.

British Academy, Burlington House, W. 5 p.m. Mr. W. R. Inge, "Medieval Paintings at Westminster."

Geological Society, Burlington House, W. 5.30 p.m. (1) Mr. J. E. Richey, "The Structural Relations of the Mosine Granites (Ireland)"; (2) Dr. W. F. Whittard, "The Stratigraphy of the Valentian Rocks of Shropshire - the Main Outcrop."

Meteorological Society, 49, Cromwell Road, S.W. 5 p.m. Municipal and County Engineers, Institution of, at the Pavilion, Torquay, 10 a.m. Annual General Meeting. Mr. Edward Willis, M.Inst.C.E., F.S.I., Presidential Address.

University of London, at the London School of Economics Houghton Street, W.C. 5 p.m. Prof. E. R. A. Seligman, "Economics and Economic Problems in the United States."

At University College, Gower Street, W.C. 5.30 p.m. Prof. Dr. R. A. S. Macalister, "Celtic Art." (Lecture III).

THURSDAY, JUNE 16. .Chemical Society, Burlington House, W. 8 p.m.

Municipal and County Engineers, Institution of, at the Pavilion, Torquay. 10 a.m. Mr. E. A. Sandford Fawcett, "The Engineering Departments of the Ministry of Health and Local Government Authorities"; Mr. G. L. Pepler, "Town Planning of Built Areas"; Major L. Roseveare, "Some Problems of Seaside Health Resorts"; Mr. F. Marsden, "Slum Areas under Housing Acts."

2.15 p.m. Sir Henry Maybury, "The Road and Transport Position in 1927"; Mr. J. D. Watson, "Sewage Disposal in 1927"; Mr. Arthur E. Collins, "Comparative Advantages of Powers for Pumping."

University of London, at University College, Gower Street, W.C. 5.30 p.m. Signor A. M. Bassani, "Carlo Goldoni," (in Italian).

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*All communications for the Society should be addressed to the Secretary, John Street,
Adelphi, W.C.(2.)*

NOTICES.

ANNUAL GENERAL MEETING

The Council hereby give notice that the One-hundred-and-seventy-third Annual General Meeting, for the purpose of receiving the Council's Report and the Financial Statement for 1926, for the revision of the By-laws, and also for the election of Officers and new Fellows, will be held, in accordance with the By-laws, on Wednesday, June 29th at 4 p.m.

(By Order of the Council)

GEORGE KENNETH MENZIES,

Secretary.

LIST OF FELLOWS.

The new edition of the List of Fellows of the Society is now ready, and copies can be obtained on application to the Secretary.

PROCEEDINGS OF THE SOCIETY.

EIGHTEENTH ORDINARY MEETING.

WEDNESDAY, APRIL 27TH, 1927.

REAR-ADMIRAL JAMES DE COURCY HAMILTON, M.V.O.,

Member of Council of the Society and Chief Officer of the London Fire
Brigade, 1903-1909, in the Chair.

The Chairman, in introducing the lecturer, said that Mr. Keay had won the Rutter Gold Medal of the Chartered Insurance Institute five years ago, after interrupting his insurance career by military service extending throughout the whole of the war period. Now Mr. Keay had carried off the Fothergill Prize of the Royal Society of Arts with an essay, of which the paper he was about to read was an abridged version.

The following paper was then read:—

FIRE WASTE (LOSS OF PROPERTY BY FIRE) AND ITS EFFECTS ON THE ECONOMICS OF NATIONAL LIFE IN GREAT BRITAIN.

(A condensed version of the Essay awarded the "Fothergill" Prize by the Royal Society of Arts.)

By G. E. KEAY, F.C.I.I.,

Of the Norwich Union Fire Office, Birmingham.

The Council must evidently have recognised the vast scope of this subject at the very outset, for they carefully refrained from laying down any restrictions as to the length of the essays to be submitted, and left every entrant full freedom of expression.

This initial foresight was subsequently confirmed by the eminent authorities who acted as Judges, and the successful essay had to be condensed to about half its full length to render it at all suitable for reading at this meeting.

The task of reduction seemed quite hopeless at first, and was only achieved at last by most drastic elimination, more especially of almost all illustration, until little more than a bare outline of the main argument remains for your attention.

Almost every experienced surveyor is accustomed to make a preliminary reconnaissance before entering upon an actual survey, and when this canon is applied to the present undertaking, the ground to be covered is found to fall into two main divisions.

These are then seen to be knit intimately together by an artificial system, and "Fire Loss," "Fire Risk," and "Fire Insurance," are conclusively established as natural and complementary sections of the full field for survey.

The logical process to pursue would perhaps be to consider cause before result, to investigate the parent problem of fire hazard before enquiring into the ultimate issue of the mischief, but if the nature, the measure, and the incidence of the loss can conveniently be established first, the subsequent task of determining the character, the control, and the course of the risk, will be undertaken with added interest.

Fire losses are often declared to be completely compensated by the agency of insurance, but any actual indemnification that is afforded by the operation of this familiar system applies only to each insured as an individual and not to the community as a whole.

Although from the individual aspect the loss is borne bodily by the underwriters concerned, from the economic aspect the aggregate national wealth is definitely depleted in each instance.

Through this regular destruction of property, plant and produce, abundant energies, which would otherwise be employed in fertile fields of fresh production, are constantly diverted into barren wastes of mere replacement; but this is not the only aspect of the evil.

The true measure of wealth laid waste must always be reckoned more by the potential than by the present worth, and along with this immediate destruction there is usually indirect injury.

Rapid restoration after a fire is now rather the rule than the exception, but even so, it is almost impossible to avoid an interval of interruption pending recovery of normal conditions of operation.

Whilst this disturbance is naturally a matter of the utmost concern to those immediately interested, there is generally a certain margin of productive capacity in the remainder of the industry affected, and then there is no actual decrease in national production, but simply a temporary deviation to other home channels, where the volume of trade so released is soon absorbed.

This compensating factor of industrial elasticity does not operate, however, in the case of a monopoly, either general or local ; for whether it be the sole source of some special commodity, or, say, the village gas-works, that is destroyed, the failure of production in that particular field is naturally absolute.

Moreover, even when the circumstances are such that the trade released is automatically absorbed elsewhere, the incidental internal deflection can hardly be accomplished without industry as a whole experiencing a certain loss through economic friction operating against ready redistribution.

Although a fire is frequently followed by a corresponding increase of business in competitive concerns or companion industries, the action of all associated factors of production or distribution must inevitably be suspended on the failure of the necessary accommodation, services, equipment, or material ; and this further loophole of loss may be a most serious matter.

The premises must naturally lie economically idle until reconstruction is sufficiently advanced, and the normal circulation of the capital attaching to the business is bound to be disturbed, even though the commercial confusion that would otherwise be caused by sudden call in such an emergency is now so largely relieved under the prevalent system of insurance.

The most serious consideration of all, however, is the suspension of employment for the workpeople concerned, for although they may be deemed free to accept immediate engagement elsewhere, it is very unusual to find sufficient demand to absorb them all, and the recognised lack of mobility of labour tends to enforced idleness in the interim.

Neither capital nor labour can rest unemployed, even for a comparatively short time, without considerable economic cost, as standing charges always continue to accrue and existence to require support.

Then, only too often, the particular item of property destroyed is not simply a self-contained unit, but forms a link in a chain of operations in an individual business, or perhaps one of a series of inter-dependent processes throughout an entire industry, when the failure of that single part may well render the whole system altogether inactive.

So far, the consideration of the indirect effects of fire loss has been confined to

the industrial aspect, but the position is substantially the same in any other economic field.

Indeed, almost immeasurable loss would be suffered by the nation in the destruction of any of her ancient cathedrals or other famous buildings ; or of any of the paintings, sculptures, tapestries, manuscripts, or like precious relics, gathered in her art-galleries, in her museums, and in her mansions ; all the pride of her people ; numbered amongst the world's treasures ; priceless ; unique ; irreplaceable.

It is plain then that in the reckoning of the constant toll of fire waste, the cost cannot be confined to that of the direct material damage, but due account must also be taken of the further indirect injury.

Moreover, the measure of the immediate destruction is not necessarily any criterion as to that of the consequential cost, for comparatively light material damage may bring in its train most serious resultant loss.

It must not be overlooked, however, that even this force of destruction by fire may sometimes serve as an economic corrective, just as may the more familiar agencies of War, Famine, and Pestilence, and that Progress may actually be aided when barriers to development are burned away from her path.

Indeed, as property is destroyed by fire, old cities are eventually found to be replaced by new ; old buildings by new ; old power, lighting, and heating systems, and other services, by new ; old plant by new ; and old processes by new ; until the complete cost of reconstruction may ultimately be compensated by the greater benefits enjoyed under improved conditions of operation.

The average annual cost of direct material fire loss in this country has lately been put at some twelve millions of pounds, but even this high figure must be qualified as incomplete without proper provision for Fire Brigade maintenance and Fire Insurance administration, two additional items which have been held to bring the figure up to the vast sum of twenty-five millions sterling.

Neither the original nor the amended estimate, however, takes into account the many indirect losses which have just been considered, most likely because the measure of these can hardly be calculated as can that of the direct destruction.

Again, the average annual number of lives so cruelly sacrificed to fire is put at about four hundred, and that of persons seriously injured at one thousand ; still further national losses, which, however, can no more be reckoned by ordinary standards than can the sore harm occasioned by the confusion, anxiety, distress, grief, or suffering, almost always associated with an actual outbreak.

Though these further phases of the evil are so serious in themselves, they are all outside the accepted scope of the present problem, and it is probably by no means extravagant if the aggregate annual cost of Fire Waste, direct and indirect, apart altogether from the price paid for protection and the constant toll of life and limb, be kept at the corrected estimate of twenty-five millions sterling.

Further emphasis of the gravity of the evil would hardly seem to be necessary after these few facts, yet it is surprising to find that the great body of the public would immediately and indignantly deny that the community labours under any such burden.

The man-in-the-street is quite satisfied that, as the result of the prevalent practice of insurance, whatever load there might otherwise be, is automatically and instantly lifted away from the shoulders of the public over to those of the Fire Offices; by whom alone it is borne; whose proper concern it is; and in whose fortunes he repudiates the least vestige of interest.

The true function of insurance, however, is simply to secure that the burden of any particular peril may be so spread between all those contributing to the common fund as to light gently over the whole body rather than to fall severely upon the unfortunate few.

Rarely is it recognised though, that whilst the individual incidence of the evil may be evenly distributed by the operation of this system, and the harm may be hardly so apparent, the aggregate loss sustained is no whit relieved, except, of course, indirectly.

Hardly any undertaking can be conducted without the use of certain property exposed to danger of damage or destruction by fire, and consequently requiring premium payment, but the distributive action of the system is much more complete than this, and in its ultimate economic effect the familiar principle of fire insurance is a remarkably thorough agency of indirect contribution, which embraces every responsible member of the community.

Except for the comparatively small proportion of fire insurance premiums relating to purely private interests, their cost cannot be borne personally by each original contributor, but simply figures as one of the overhead charges of every business, and in that capacity must naturally be taken into account in the correct costing of whatsoever article or service is supplied.

Hardly any commodity reaches the retail market without passing through a whole system of different fields of production, manipulation, and distribution, and at each separate stage throughout its progress an appropriate premium accumulates, not merely in respect of the risk attaching to the article itself during its passage through that particular field, but also, proportionately, in respect of all or any buildings, plant, services and supplies, incidental to that individual link in the chain, until, eventually, the grand total of these several successive charges must inevitably figure in the retail cost and be borne by the ultimate consumer.

This unique machinery of distribution serves to spread the full strain of material fire waste over the whole of the community, and the national loss is met by contributions collected indirectly, but none the less certainly, from each and every inhabitant in direct proportion to purchasing power.

Likewise, the many indirect losses are also borne eventually by the public at large, as, indeed, is every form of national waste, and though the action of the

economic machinery accomplishing their distribution is far more intricate in detail than that of the system of fire insurance, it is substantially similar in principle, and the ultimate result is none the less certain.

This powerful truth is of such general concern that it would be well were it broadcast loud throughout the land that each loaf of bread, each pair of boots, each ounce of tobacco, indeed, each and every conceivable commodity, and therefore the actual cost of living, would inevitably be cheaper were it not for the loading every single purchase must bear as a share towards the national fire waste reckoning.

This definite demonstration of the ultimate individual incidence of all Fire-Waste should surely be sufficient to warrant the recognition of Fire Insurance as a natural and indispensable section of any essay on the subject, but the practice of fire underwriting has now reached so high a stage of development, and exercises so intimate an influence over the actual circumstances of both Fire Loss and Fire Risk, that the present survey would be integrally incomplete without further consideration of the economic action of the system.

The first feature to attract observation is that the development of fire insurance has unfortunately been allowed to distract proper public attention from the true nature, extent and incidence of fire loss ; from the real seat of responsibility for the provision of protection against this peril ; and from the technical treatment of the pressing problem of fire risk.

The popular impression concerning the burden of Fire Waste has already been corrected, and a kindred delusion is that, inasmuch as the Insurance Offices reap an immediate benefit from municipal measures of minimisation, they should either bear the complete cost of the maintenance of such services themselves, or else be compelled to contribute on a uniform basis.

Actually, however, the proper duty of the Offices is simply to undertake the equitable distribution of fire loss, and that of the public, both collectively and individually, to exercise every precaution against fire risk that would be taken had no such system as that of insurance ever been established.

The provision of proper protection against public peril is distinctly a duty devolving upon the appointed representatives of the community, but although it is now authoritatively allowed that the maintenance of such services is one of the first responsibilities attaching to any local body, only too many still fail to recognise the true position, and to appreciate the acute need for such work.

Moreover, the fact must be faced that the general problem of fire risk has not been allowed anything approaching adequate attention, for whilst our Fire Brigades have such an excellent record of heroic deed and public service, and are always ready to give every information and assistance within their power, their activities must naturally be devoted more to matters of rescue and extinguishment than to general considerations of fire risk.

Had no such system as that of insurance ever been established, public concern must long ago have led to the institution of a national Fire Protection Service, directly responsible for prevention, which here, as always, is so much better than any cure.

A further direction in which the system of insurance tends towards the creation of loss is that it is often allowed to develop the deterioration of rightful responsibility.

Though so many concerns and so many individuals make it almost a point of honour ever to exercise as much vigilance as if they were running their own risk, the general standard of care would naturally be improved, were it not for the relief of responsibility brought about, consciously or otherwise, by the mere availability of insurance.

Yet another way in which this system is found to occasion actual loss is through fire being raised deliberately, with a view to fraudulent recovery at the ultimate expense of the community at large, an evil properly attributable to the inevitable element of criminal inclination.

Though these several considerations can hardly fail to swell the national burden of Fire Waste, any such indirect action is not so much the fault of the system itself as the natural outcome of the essential frailty of human nature, the balance preponderating entirely in favour of insurance as an excellent economic asset.

Our system of fire insurance is administered mainly by public companies, which act as an agency of distribution, or, as it were, conduct a "clearing-house," and the first cost of the anticipated loss is inevitably increased by charges for business acquisition, expenses of administration, interest upon capital entailed, and profit for adventure undertaken.

This additional cost is compensated manifold, however, by substantial relief in other directions, since, but for the confidence created amongst the community by the indemnity of insurance, fresh fields of wealth would often be left entirely uncultivated, and rich harvests lost to the country through dread of disaster; whilst, without this support, the vast system of credit on which modern life is so largely dependent could hardly have been built, or, once constructed, endure.

Even the indirect injuries are all substantially relieved in their several fields through the provision of financial facilities for ready reconstruction after an outbreak, and yet again, the very methods on which fire underwriting is now conducted are in themselves a powerful agency in the reduction of hazard.

Whilst the early underwriter was sufficiently content to exercise his judgment as to the measure of a risk laid before him exactly as he found it, without concerning himself in the least over any possibilities of improvement, the position is vastly different to-day.

Under each of the trade "tariffs," or differential graduated scales of insurance charges applicable to the various industries, appropriate extras are

exacted for established hazards, and corresponding concessions allowed for approved safeguards; the ordinary law of commercial competition then operating so that in seeking to retain old connections and to secure new business each Office must continually educate the public as to what physical alterations may be made to obtain the most favourable treatment.

Careful comparison with corresponding conditions abroad has proved beyond any shadow of doubt that the segregation of hazardous processes from the main range which is now so general in certain industries here, has been brought about solely by this organised action of the associated Offices; whilst it is hardly likely that the use of methods of fire-resisting construction; the installation of automatic sprinklers and fire-alarms and of drenchers; the provision of private fire extinguishing appliances; and the adoption of many other safety devices; would yet have attained the present stage of development, had it not been for the substantial discounts allowed for such safeguards.

Furthermore, in the ordinary course of their regular inspections, the trained surveyors of the Insurance Offices are constantly discovering dangerous defects which are usually remedied forthwith on being brought to the notice of the proper authority at the particular premises.

The qualified Fire Surveyor has long been recognised by the discerning public with whom his work brings him into contact as specially skilled in the subtle mysteries of fire risk, and it is by no means uncommon for him to be called into consultation when changes are contemplated, and for his suggestions to be adopted wherever they do not conflict unduly with considerations of economy or convenience.

Indeed, more usually than otherwise, any reasonable recommendations he is able to put forward are warmly welcomed by progressive parties as completely co-incident with entirely independent principles of good management, and as introducing internal economies which more than compensate for their adoption, altogether apart from any question of improvement in fire hazard.

The one authority to whom works' executives throughout the country constantly turn for information and guidance in all matters of fire risk is their particular insurance company, and whether or no this position may have arisen simply because no additional charge is made for such services, the most powerful agent in the education of the public regarding the reduction of fire hazard is undoubtedly the system of fire insurance as at present administered here.

Moreover, the Fire Offices' Committee has established an elaborately equipped testing-station, where exhaustive experiments are regularly made as to the efficiency of various safety devices, and as to problems of fire hazard of almost every description.

Again, it has been left to the associated Companies to establish permanent Salvage Corps in such cities as London, Glasgow, and Liverpool; whilst in this last centre extensive premises have been erected complete with kilns, presses, and other plant requisite to the proper handling of cotton salvage.

The salvage men are often busily engaged even whilst the flames are still raging, and their fire duties embrace every possible means calculated to leave the regular Brigade free to concentrate upon their main responsibility of the rescue of life and the prevention of conflagration.

Coupled with this useful work, the staff are otherwise engaged in the inspection of mercantile premises, in the testing of private fire appliances, and in patrol work in certain centres where there are vast aggregations of valuable property.

Though it is evidently expedient for the Offices to maintain such Salvage Corps, it is no more part of their proper duty to do so than to provide their own Fire Brigades, and the development of this movement in other large centres would certainly seem to merit most careful consideration.

The triple benefit of the encouragement of adventure, the stabilisation of credit, and the relief of indirect injury, is simply a natural result of properly directed co-operative effort, but this further work of the lessening of actual destruction is altogether supererogatory.

Though the true function of the system is not concerned with the reduction of material damage, aiming merely at the equitable distribution of the initial incidence of the mischief, even this cursory treatment of the economic action of Insurance over the circumstances of Fire Waste should be sufficient to shew that consideration of the subsidiary system cannot possibly be divorced from that of the parent problem.

The general character of fire risk must now receive certain consideration, and the first thing needful is to establish the natural laws governing the growth of the danger of fire from degree to degree, a force which is known in fire insurance circles as that of "Accumulation."

All that is possible here, however, is the barest outline of what I have ventured to christen my "Factorial Theory of Accumulation," and even this short summary would have been omitted in the exigencies of condensation, were it not that the main principles of the doctrine seem to provide the only solid foundation for constructive education in the matter of fire risk.

Resultant fire risk in general may first be conceived as comprising three entirely distinct quantities, the "Natural Element," the "Personal Element," and the "Physical Element."

Destruction by fire is sometimes occasioned by purely natural agencies, such as lightning, tempest, earthquake, and eruption, but these forces are beyond the accepted scope of the subject and need not be given further attention here, save for the disquieting but inevitable reflection that past freedom from disaster carries no warrant of future immunity.

The "Personal Factor" may be resolved into two main divisions, the "Incendiary Element," that concerned with deliberate raising or release of fire, and the "Maintenance Element," that concerned with the accidental inception or escape of fire.

In the great majority of instances, the "Incendiary Element" is, normally, so remote as to be negligible, and this factor must be eliminated from the problem of "Accumulation" at the present stage as an altogether extraneous and unstable quantity.

The "Maintenance Element" may be defined as the standard of condition and care, and includes, besides the precautions proper to different materials, operations, processes, and circumstances, such common considerations as "Age," "Accommodation," "Management," and "Morale."

On examination, however, all these considerations are found to be reflected in actual physical features, such as the provision or absence of appropriate safeguards; the substance or poverty of construction; the suitability or otherwise of occupation; the regularity or neglect of lubrication; and the removal or accumulation of refuse.

This quantity of "Maintenance" then is hardly so much an integral factor of the ultimate equation of risk as an independent force governing the measure of these physical hazards, and it is rather to them that attention must be devoted if proper progress is to be achieved.

Although physical fire hazard in general is commonly conceived as merely the danger of initial outbreak, actually it is rather a composite than a simple force, and comprises certain complementary constituents, which may be termed "Fire Risk Factors."

The resultant physical risk of any subject-matter whatever may readily be resolved into three distinct primary components, the "Outbreak Factor," the "Extinguishment Factor," and the "Susceptibility Factor."

These three terms indicate respectively the possibility of the occurrence of fortuitous fire in material degree; that of the subsequent arrest of such a fire; and the varying capacity for damage of different classes of property when exposed to the same general risk.

Each of these primary elements may readily be reduced to secondary factors; these again to tertiary; and the process continued still lower, until a complete analysis may be constructed providing full and proper accommodation for every conceivable feature which may be found to contribute to the measure of fire risk.

The initial "Outbreak Factor" may be divided forthwith into the secondary factors of "Inception" and "Development"; both of which may readily be resolved into tertiary factors; that of "Inception" into "Ignition" and "Nucleus"; and that of "Development" into "Fuel" and "Flue".

Similarly, the primary "Extinguishment" factor may be reduced into the secondary factors of "Time" and "Service"; and both of these may also be resolved into tertiary factors; that of "Time" into "Detection" (including communication of alarm) and "Assembly" (embracing means and conditions of access); and that of "Service" into "Brigade" (including matters of personnel and equipment) and "Water" (comprising considerations of volume and pressure).

The remaining primary factor of "Susceptibility" varies only as between different subject-matters within one and the same general field, as, for instance, the structure, the plant, and the stock in a sprinklered factory of fire-resisting construction, and hardly enters into the problem from the economic standpoint, though such a significant quantity in connection with the comparative measurement of fire hazard.

Fire Waste, however, must always be understood to include, not only loss occasioned through actual combustion, but also that resulting from consequent explosion; collapse; fracture; water, smoke, taint and exposure damage; temperature variation, and process interruption.

The twin principles of the initial independence and the complementary combination of these several basic factors having been established, it is next necessary to conceive the practicability of a series of scales for the measurement of fire risk factors of the various classes, whereby comparison could be made between the relative constituent and resultant hazards of different features and subject-matters.

If only such a system were practicable, indices obtained for hazards and safeguards of the same *general* character would, of course, simply require adding or subtracting to obtain the net value of that particular factor, the sum of the hazards giving the aggregate value of the class, against which would have to be set off the sum of any corresponding safeguards.

Hazards or safeguards of separate or *complementary* classes, however, would be as distinct as, say, temperature, pressure, and volume; and values ascertained, for instance, for "Inception," "Development," and "Susceptibility," could no more be added together than can feet, volts, and therms.

Though clearly impossible of addition, factors of these different classes might, however, be quite capable of combination in an equation, just as may temperature, pressure, and volume; and the combination of hazards of *complementary* character must clearly be measured by the *product*, instead of the sum, of their values.

If simple representative examples of different features of fire risk be conceived, each of the value of, say, ten units in their respective classes; when any three are exhibited together, if they are all of the *same* class, their sum is but thirty, whilst if they are of *complementary* classes, their resultant is a thousand; and here in this striking difference between thirty and a thousand lies the whole substance of the factorial theory of accumulation.

A common and natural enquiry in connection with the study of the comparative fire risk of different processes of manufacture is as to the outstanding hazard of some industry which is known to possess an unfavourable fire record, and in the great majority of instances the only proper answer is that this lies in no one feature alone, but rather in the untoward association of certain complementary factors, such combination then being said to introduce accumulation of risk.

The position is exactly the same with regard to many general features which experience shews may be taken as representative of associated dangers, more particularly such common hazards as "Capacity," "Height," "Age," "Defective Construction," "Congestion," "Plurality of Tenure," "Combination of Trades," and "Isolation;" each of which imports pronounced accumulation.

It is evident then that any economic development which is found to introduce *complementary* rather than *similar* conditions of fire hazard must exercise an intimate influence over the measure of Fire Waste, and without this brief outline of the factorial theory of accumulation it would hardly be possible to undertake the constructive consideration of the control and the course of fire risk.

Fire is one of the chief of the elements of Nature as yet employed by Man to serve his ever-growing need, but as with all her vast forces, Fire is beneficial only whilst competently harnessed and legitimately exercised, for immediately on any failure of perfect control or on any deviation from proper use the willing servant becomes a ruthless master.

A certain drain upon the wealth of the country through the medium of Fire Waste must evidently be accepted as one of those penalties almost always associated with the rewards of Progress, for even if every care were exercised and every precaution taken which might reasonably be expected of a prudent citizen fairly familiar with the particular hazards involved, there would still be a remainder of risk, owing to the essential imperfections in Man's general behaviour and in his command over the forces of Nature.

Apart from this natural and inevitable residuum, however, the original inception or escape of fire is mainly governed by the sufficiency of the care exercised and the adequacy of the precautions adopted, and consequently the great proportion of Fire Waste, far from being absolute, is characteristically capable of considerable control.

Whilst the average individual is naturally imbued with a proper sense of his private and public responsibility, there is always a tendency for him to take certain risks to the possible prejudice of the community, and the extent to which such control as conceivably might be exercised in theory actually is exercised in practice is governed by two main considerations, "Education" and "Legislation."

The capacity of Man's control over Fire is relatively the same as that over any other element of Nature he has learnt to press into his service, his power over these vast forces being governed by his knowledge of the physical processes of the individual elements; but his general understanding of physical fire hazard is strangely elementary, especially considering the prominent part that Fire plays in modern life.

Except where the laxity of maintenance is such that familiarity is found to

breed contempt, the perils of the introduction of petrol or celluloid in bulk and of similar special hazards are so palpable that reasonable precautions are usually taken, but the ordinary and elementary dangers, which ought to be quite familiar, regularly escape recognition.

Most useful progress has already been achieved, both in the study of common fire hazards and in that of the special risks of different industries, and a rich harvest of knowledge lies garnered in the archives of various interested institutions, whose members are kept regularly supplied with the latest intelligence relating to fire risk.

The best interests of the Nation, however, would surely seem to call for the formation of one parent body for the collection and dissemination of such valuable information, and for general research in matters of fire hazard.

Moreover, there is no proper provision for the enlightenment of the masses in this most important matter, though it is with the general public that the reduction of Fire Waste is best to be achieved.

The most successful measures of minimisation must naturally be those directed towards original contraception, both as regards the avoidance of outbreaks occasioned by immediate human action, and as regards the timely detection of those of other origin.

It is clear, therefore, that the closer control of fire risk lies largely in the power of the people, themselves the actual sufferers; and proper education of the masses in the elementary economics of Fire Waste and the primary principles of Fire Risk should be sufficient to secure an abiding improvement in the measure of the mischief.

It is hardly possible here to enter upon anything beyond the most superficial treatment of the subject of legislation against fire risk, more especially in view of the great divergence existing between the responsibilities, the powers, and the practices, of different cities, towns, and districts; a divergence which involves the whole problem of local government administration.

Such enactments as exist are chiefly concerned with the control of hazardous trades, the observance of building regulations, and the provision of emergency exits; ordinances all aimed principally at the preservation of human life and at the minimisation of conflagration risk, and only subordinately at the general reduction of Fire Waste.

Local building regulations exhibit a surprising variety of scope and stringency throughout the country, but even though the feature of "Age" is perhaps the most serious of all common fire hazards, their application can hardly be made retrospective to premises already in existence at the time of their introduction; whilst except for those regulations relating to some few trades scheduled as "Dangerous," there is no legal machinery for exercising proper control over the standard of safety of individual buildings.

If there were put into operation a regular system of inspection by competent

surveyors, officially empowered to procure the remedy of avoidable fire hazard defects, the loss experience should soon be substantially improved, and it should not be difficult to combine this desirable work quite readily and at a minimum of additional expense with that at present undertaken by existing departments.

Again, even though the principle is commonly conceded that adequate fire protection is as acute a need of the modern community as pure drinking water, sound sanitation, and a proper police-force, local authorities seem hardly so much actually compelled to institute appropriate regulations and to maintain an efficient water supply and Brigade service, as simply empowered to do so if they see fit, entirely at their own discretion.

Competent facilities for fire extinguishment are usually provided in progressive centres, but in only too many parts of the country such services are still utterly inadequate; whilst, to our sore disgrace, a public Brigade may sometimes have to deny their services, even when actually attending a fire, on the grounds that the burning building happens to lie outside their own particular area.

There is obviously a real need for some proper co-ordination of public fire extinguishing services on a convenient regional basis so that no part of the country may be without adequate protection; and it is a matter of great regret that emergency arrangements of this character introduced for a time during the War were allowed to lapse with the Defence of the Realm Act.

The certainty of thorough enquiry after every outbreak is held to be a far more successful deterrent against actual incendiarism and improper conditions than provision for the most severe punishment in the event of detection, and the institution of a general system of Fire Inquests, similar to that obtaining in the City of London, is strongly recommended.

Actual experience abroad has proved that any additional expense would be amply compensated by a definite improvement in the measure of loss sustained, quite apart from the greater knowledge of matters of fire risk that would naturally be gained through such systematic investigations, and the necessary machinery could probably be combined quite conveniently with the present duties of the Officers of the Fire Brigade and the Assessors to the Insurance Offices.

Whilst there is a constant outcry for less interference with the liberty of the subject, the welfare of the community should always prevail, and it must be borne in mind that Fire Waste is more a public than a private menace.

There is evidently every opportunity for considerably closer control to be exercised over this constant drain upon National resources before any fear need be entertained of improper interference in economic affairs.

The last stage of this survey is concerned with the consideration of whether the general measure of Fire Risk here be stationary or changing, and if changing, whether decreasing or increasing.

Unfortunately, it is almost impossible to draw any definite conclusion as to

the present trend of the mischief from fire loss records, since not only is the aggregate amount of national wealth constantly growing, but the monetary value by which it is measured is almost as continually varying, twin considerations which necessitate careful correction before any true comparison can possibly be made.

An even greater difficulty is introduced through the irregular incidence of the conflagration element, an altogether uncertain quantity which renders loss statistics subject to considerable fluctuation, and the course of the mischief is to be found in one way only, that is by the application of the principles of accumulation to the established action of economic forces.

The natural element of compensation must always be borne in mind when considering the direction of modern developments, since no such feature or force necessarily influences the measure of fire risk in one direction alone, the effect usually being complex, but attention to certain main impulses must suffice for present purposes.

My earlier analysis of basic fire risk factors may well be deemed rash, and it would be almost an impertinence for me to attempt the like treatment of modern economic developments.

However, the initial grouping of fire risk factors into "Natural," "Personal," and "Physical," may conveniently be taken as a guide, and the effect of Progress on the course of Fire Risk may be considered in three main bearings, the "Natural," the "Social," and the "Industrial."

The "Natural" element of Progress is conceived as that represented by the twin forces of "Age" and "Change," both of which exert a most active influence on the general measure of fire hazard.

The power of this peril, as of almost every mischief other than the passing weaknesses of youth, grows fast with the age of the subject, and the natural deterioration of a building owing to age is accompanied by several serious hazards, carrying in combination considerable accumulation of risk, which can only continue to accrue until the particular premises are abandoned, reconstructed, or destroyed.

In addition to "Age," Time brings also constant "Change," and this further element exercises as powerful a force on the measure of fire risk as does the companion factor of decay.

The passage of Time perpetually presents new types of construction; new systems of lighting, heating, ventilation, and power; new processes; new operations; new materials; and new conditions; and every single one of these features may introduce not only new degrees of known hazards, but also entirely fresh elements of danger.

Though such excellent progress has been made, particularly of late years, in the minimisation of fire risk and in the betterment of facilities for escape, rescue, extinguishment, and salvage; and though it is popularly held that any further danger there might otherwise be is more than counteracted by the

fruits of modern invention ; actually these improvements are not found until the after-search for proper protection.

As new dangers come to be known by Man, his attention is devoted to the perfection of suitable safeguards, though, only too often, these are not adopted generally until public indignation has been aroused by some sad catastrophe.

The natural conclusion is that there must always be a certain interval between the initial liability to the perpetual penalties of progress and the subsequent adoption of adequate safeguards ; and this unfortunate "time-lag" seems particularly pronounced in connection with the present problem of Fire Risk.

Perhaps the most prominent, and at the same time the most perilous, feature, however, is the natural and general attempt to reconcile Age with Progress, to put new wine into old bottles, and it is evident that the natural and inevitable factor of "Time" alone brings constant accumulation of risk, and cannot fail to add to the burden of Fire Waste, unless sufficient compensation be introduced by the operation of the "Social" and the "Industrial" elements.

The "Social" element is taken to represent the position of the Public, both collectively and individually, in the matter of fire risk ; a factor which invites attention, as did the original personal quantity, by discriminating between intentional fires and accidental fires.

Anything approaching an adequate analysis of the many motives responsible for incendiarism would, naturally, require altogether separate treatment, but for present purposes they may be resolved into main considerations of "Irresponsibility," "Malice," "Concealment or Publicity," and "Cupidity."

Except in times of acute depression or unrest, the deliberate raising of fire, though certainly serious of itself, probably contributes only a small proportion both to the total number of outbreaks and to the aggregate resultant loss ; but the whole question is naturally most uncertain.

The chief common criterion of fire risk, however, is the "Maintenance" element, which is governed almost entirely by the sense of responsibility.

Though outbreaks may occasionally be traced to circumstances which are altogether exceptional, by far the greatest proportion of fires are due either to immediate personal carelessness, or to failure to remedy quite ordinary defects, and trite though the observation may seem, it is impossible to over-emphasise the fact that if only reasonable care were always taken and proper vigilance constantly maintained, the measure of fire risk would be most materially improved.

It is a matter of grave concern, therefore, to find that the present age is often declared to be essentially one of irresponsibility, and it would certainly seem that if the present tendencies are allowed to develop uncorrected, the measure of fire risk must continually be increasing as regards this "Social" factor also.

All that now remains to be considered is the "Industrial" aspect of the problem, and particularly prominent amongst the present powerful forces of progress is that phase of development evidenced industrially in

increased congestion of situation ; increased capacity of particular premises ; increased height of individual buildings ; increased measure of power utilised ; and especially increased pressure of production ; all features which introduce elements of danger inherent to each and carry in their combination pronounced accumulation of risk.

The development of this line of thought leads inevitably to the problem of " Conflagration Hazard," which to-day is such a real and constant risk in many parts of the country, though generally dismissed by the Public as nothing but a pet chimera of the Insurance Offices.

Whilst certain considerations of compensation must be conceded, it would seem that this active force of Industrial development introduces a decided additional hazard, and in view of the identical direction of the " Natural " and the " Social " elements already debated, there can be little room for doubt that, far from being relieved, the general measure of fire risk here is actually increasing, almost from day to day.

The various observations that have been made in the course of this superficial survey may now be brought into proper perspective, when it is seen that the predominant problem is hardly so much the influence of Fire Waste upon Prosperity as that of Progress upon Fire Risk, and that the time is now ripe for the declaration of a general crusade against this grave national mischief.

The first step in the prosecution of such a campaign must clearly be the institution of a proper system of public instruction in the principles of Fire Waste and Fire Risk, the natural development of which may be relied upon to bring welcome relief in the measure of the loss and a material improvement in both general and individual well-being.

DISCUSSION.

The Chairman, in opening the discussion, said he noticed that in a lecture given by Professor Lewis, of Greenwich College, in 1906, it had been stated that the annual fire waste in the British Isles amounted to £70,000,000. Personally, he did not know whether that figure was then correct, but if it was, then fire waste, according to Mr. Keay's figures, had gone down a great deal in this country since 1906.

With regard to the prevention of fire waste, there was no doubt (although he did not think that everyone recognised it) that the fire brigades did take a great deal of trouble about prevention with their inspection staffs ; and the Salvage Corps to a still greater extent. There was no doubt, also, that fire waste would be far greater if it were not for the regulations and instructions which were issued by the fire insurance offices. He knew from experience how very keen those offices were in the matter of insisting that everything in a building should be kept up-to-date. When he was in the Fire Brigade he did not worry much about those regulations and instructions, but now that he shared the responsibility for a number of big buildings he found them a nuisance !

With regard to co-ordination and national fire prevention service, the people of

this country did not like to be controlled more than was absolutely necessary ; nevertheless, co-ordination in this matter was required. Sir Sampson Sladen and himself had worked together on the Fire Advisory Committee of the Ministry of Munitions during the war, and had had to do with all the munition factories and aerodromes, and he could only say that if some of the measures which had been adopted then had been continued after the war it would have been a very good thing for the country. At the Ministry of Munitions he had had under him a very able gentleman—Colonel Symons—who had organised and divided the country into areas, and had connected all the fire brigades in each area with one central fire authority for that area. Every fire brigade, whether it belonged to a borough council or to a county council, was subject to the central control, and had to obey instructions. That method had been found to be most efficacious, and the fire brigades seemed to appreciate the system ; it had given them more scope, and they had felt that they were more in touch with one another. Although a strong report had been sent in that such a system should continue after the war—co-ordination of the fire services generally in some form—the matter had been shelved.

He did not agree with Mr. Keay in thinking that the Salvage Corps should be organised on a national basis as well as the Fire Brigades. The Salvage Corps were in a very fine position—and there was no doubt that they were a very fine corps. There was a certain amount of emulation between the Fire Brigade and the Salvage Corps, which was all for the good of fire matters generally ; and if the Salvage Corps were brought into closer connection with the firemen he thought it would be found that they would all want to be saving lives and would neglect their proper duty, which was that of saving goods and clearing up the debris.

He did not know how far Mr. Keay intended to extend his idea of fire inquests. Surely he did not mean to suggest that there should be an inquest on every fire that occurred, because fires in London ran into double figures every day, and there could not possibly be inquests on every one. If there were, half the Fire Brigade would always be in the Courts.

He might mention that the Fothergill Prize was founded on a bequest of £500, to be laid out in medals or premiums in furtherance of the following objects :—“ The best method of preventing destructive fires and of detecting incendiaries ; secondly, of speedily extinguishing fires when water is scarce ; thirdly, of speedily securing valuable property from the flames and also from thieves ; fourthly, of preventing or diminishing the numerous fatal disasters from fashionable muslin dresses catching fire, whether by rendering such dresses less combustible or having constantly in readiness a large cloak of incombustible fabric composed of asbestos or amianthus with which instantly to wrap the whole body ; and, lastly, of preserving from fire valuable deeds and other manuscripts. The above to be varied at the Society's discretion.” The Society allowed the amount of money to lie out at interest for so many years, and when a sufficient sum had accrued the matter was taken in hand. If anyone present would like to leave money to the Society in trust for any purpose the Society would always be glad to receive it. The Society already had a long list of monies entrusted to it, which were always dealt with in the most admirable way. He might mention that Members of the Council were not allowed to receive any monetary advantage or any medals or certificates connected with the Society.

MR. E. C. BRYANT said Mr. Keay had referred to the effect of the work done by the Insurance Companies in reducing the number of fires, but the figures did not quite bear that out. Taking London, from 1914 to 1918 the average loss had been

£500,000. From 1919 to 1922, when Inglestein, the notorious incendiary, had been at work, the loss had gone up to £1,200,000. Since Inglestein had been incarcerated the loss had dropped back to £600,000. Taking England generally, for the years: 1914 to 1918 the loss had been £5,000,000 per annum, and for 1919 to 1922 it had risen to £11,000,000, dropping back in 1924 to £6,000,000.

The lecturer had talked about progress, but every fire he himself had attended had been in connection with buildings where glaring risks were shown to have been taken. He felt that the insurance companies, in their anxiety to get trade, accepted unnecessary risks in many cases. It had been his experience in the case of many fires to form the opinion that, if fire insurance had not been in existence, those fires would not have occurred.

MR. G. E. KEAY said that the points referred to by Mr. Bryant were dealt with in the full edition of the Essay. The question of incendiarism was naturally a most difficult one. Incendiarism not only involved a risk being created merely in connection with the property the incendiary desired to destroy; it might extend to property of innocent parties, but it was impossible to classify fires as definitely incendiary fires without concrete and definite evidence. Mr. Bryant had said that Insurance Companies, in their eagerness to get business, would take anything. If Mr. Inglestein had tried to get his risks covered with any of the leading offices he would not have succeeded. The position was rather different with regard to fires in time of depression. Property fires were supposed to be caused by incendiarism during such times; that was the obvious explanation, but the truer explanation lay somewhere else. Times of depression meant times of financial stringency. The proper maintenance of premises was relaxed. The ordinary standards of cleanliness and good management and the observance of rules and safeguards were relaxed in times of depression, and this was due partly to financial stringency and partly to a general lowering of morale. Such, he thought, were the real causes of fire losses rising in times of industrial depression. As to work done by the Companies in preventing fires, he could say from his own experience that he had been able to get thousands of pounds spent on safeguards and improvements, and his own personal efforts could be multiplied by thousands. He thought, therefore, it was evident that Insurance Offices were doing something towards reducing fire risks.

MR. J. W. DANE (Chief Officer, Croydon Fire Brigade) endorsed Mr. Keay's remarks on the question of incendiarism. Personally he found that very few fires were due to this cause. He could only call to mind one such case in 22 years' experience in the town in which he now was. Personally he did a large amount of surveying, and knew a great deal of what insurance surveyors missed in going round a place. He had often seen something likely to cause a fire, and on pointing it out had been told, "Our insurance surveyor has passed it." Often, when a surveyor said that his Office would take the insurance at a certain rate if specified hazards were removed, the people had gone to another Office, which had taken the risk as it had stood. If fire insurance surveyors wanted to get in contact with the professional fire officers of the country, he could assure Mr. Keay that the latter would be only too pleased to do anything they could to minimise fire risks in the towns in which they served. The matter of petrol was mentioned in the paper. In that connection he could only say that it would be a very great asset if Insurance Offices would make themselves fully acquainted with the regulations appertaining to the storage of dangerous goods. If they did so, and insisted on those regulations being enforced, very much greater safety from fire would result.

In regard to municipalities denying the services of public fire brigades outside the areas they were maintained to protect, he asked Mr. Keay whether his Company would pay the loss by fire on property insured in a competing company.

Further, dealing with the expressed view of municipalities that Insurance offices should bear some portion of the cost of fire protection, this was only to be expected, as the insurance offices gave this protection in their early days, and it was only natural that the municipalities should endeavour to perpetuate the principle.

MR. G. E. KEAY said the remarks of the last speaker gave him the opportunity of making a public acknowledgment of the great debt he owed to professional fire officers throughout the Midlands. At different times and in different centres he had had occasion to visit professional fire associations, and every time he had been received with every courtesy and given every information. With the professional fire officers he would like to associate architects, and particularly the local surveyors of city and urban councils. As to what people said about their insurance offices allowing certain hazards to remain, such remarks should be discounted by 97½ per cent.!

MR. H. FRITH ALLBROOK pointed out that it seemed to him that some people were expecting too much of the Insurance Offices. They wanted the Insurance Offices to say: "You must build your house of brick; you must not have any petrol on the premises; you must have a ring of water round it, and hose sufficient to command the premises; then we will take the risk at a certain rate." That was not the business of the Insurance Offices. Their business was to meet the public want. The Offices were obliged to charge different rates according to the risk, and a rate might progress from 7s. 6d. to £1 1s. 0d. on account of various features which increased the hazard, *e.g.*, 1s. 6d. for opposing windows; another 1s. 6d. for plurality of tenure, and so on. That was because the Insurance Offices recognised that they must vary the rate according to the risk. The Insurance Offices could suggest that there should be a co-ordination of fire brigades, and if that became law it would be better for the whole country; but the Insurance Offices could not say that there *must* be a co-ordination of the fire brigades.

MR. E. HOWARD WILKINS (President of the Corporation of Insurance Brokers) said that having devoted fifty years of his life to the study of fire insurance, he desired to pay a tribute to the efficiency of the fire surveyors of the Insurance Companies. In regard to the question of a Central Research body, that, to his mind, was a most essential thing, and would effect a vast saving in the fire waste of this country. He had had a recent unfortunate experience of the difficulty of getting the English Insurance Companies to recognise a certain fire-proof material. Although it had been recognised in America and by the London County Council as a most valuable fire-proof material, the Insurance Companies had said: "No, we do not recognise it as a first-class fire-resisting material." He had himself put that particular material over an anthracite cooking stove for 1½ hours in the form of a tile, and had afterwards examined and tested it in every way, and he found that no change had taken place in it. Yet, as he had said, the Insurance Companies would not pass it. A Central Authority was necessary for testing materials and for proving the advantages of inventions which were to hand.

MR. W. B. ZAPPERT (late Chief Officer, Alexandria Fire Brigade) remarked that it was only fair to various inventors both in this country and abroad to point out that some very adequate appliances and inventions had been introduced which

would effectively deal with fire risks. Owing, however, to lack of courage on the part of the powers that be those inventions had not been brought into use until the damage had been done. There were at the present day some very fine inventions which would meet, as far as it was humanly possible to meet, all the risks that could be anticipated for the next five or ten years, but evidently they were not known to the average Insurance Company.

MR. ALEXANDER MACDOUGALL said, as one who had had to handle oil and petrol in bulk and in cans and other forms for the last thirty years, he endorsed Mr. Keay's demand that a Central Authority should be created to deal with the whole system of petrol storage. He had found that different local authorities dealt with that question in entirely different, and in some cases entirely inadequate, ways. While, however, he would like to see the matter brought under one Central Authority, he would not wish to see a cast-iron set of regulations established, but certain broad rules should be laid down. Every case should be dealt with on its merits, and care should be taken, in the working of any such regulations, to allow a certain amount of elasticity to the chief officers concerned after their Inspectors had reported on the schemes: the Chief Officers visiting the sites, if found desirable. Speaking generally, he considered London (L.C.C. area) fortunate in this respect.

MR. JAMES CAWSON remarked that he had had occasion to arrange a fire policy some short time ago, but before the Insurance Company accepted the risk they had sent their surveyor to inspect it, when the surveyor had pointed out a certain piece of rubber tubing which conceivably might constitute a hazard. That showed that the Insurance Companies were very careful not to incur unnecessary risks to themselves, which was really in the interests of the insurer.

COMMANDER A. FIREBRACE, R.N. (London Fire Brigade), referring to the question of fire-proof doors, said that just as watertight doors afloat were of no use unless they were closed, so in the same way fireproof doors in large buildings were of not the slightest value in a fire unless they were shut. Those who had practical experience in the extinction of fires knew that they often found fire-proof doors left open at a fire. One good point made by the lecturer had been that no fire protective arrangement got anywhere at all unless the Insurance Companies offered a rebate on it. He would like, therefore, to throw out the suggestion that there should be installed in all large buildings an arrangement whereby it could be indicated, in the lobby for instance, whether all doors in the building were shut or open, and that a rebate should be given if such a device were installed. If it were installed, the night watchman or any insurance surveyor or fire brigade official could, from the outside of the building, see whether the doors were open or closed at night.

He asked the lecturer if he could really substantiate his statement that a public fire brigade sometimes had to deny their services even when actually attending a fire, on the ground that the burning building happened to lie outside their own area. It did seem contrary to all fire brigade views that if a brigade attended a fire and found it was five yards outside its area it returned home again.

MR. G. E. KEAY, in reply to Commander Firebrace, said that practically every modern fire-proof door was fitted with an appliance which rendered it automatically self-closing. Commander Firebrace's suggestion was worthy of very careful consideration, but it had to be remembered that those doors had to be sold to the public, and from his personal experience he could say that the public said that

fire-proof doors cost about ten times as much as they should do already, and if another item of expense was introduced it would be very difficult to get any installed at all. With regard to Commander Firebrace's last point, there were stories of such occurrences happening, but personally he did not propose to confirm it or deny it. He believed that if the archives of some of the newspapers were carefully searched, interesting information on the point could be found.

MR. F. R. JORDAN said that little had been said on the subject of fire prevention in the paper which had been placed before the audience. He did not know whether that matter was more fully dealt with in the fuller edition of the lecture. The same applied to the question of fire detection. The Report of the Royal Commission on Fire Brigades and Fire Prevention advocated the more general adoption of automatic fire detection and fire prevention appliances. Three thousand six hundred fires broke out in London every year, of which thirty-six were serious fires. Those thirty-six fires per annum involved 94% of the total fire losses in London, and the remarkable point was that those fires did not make themselves known until, on the average, 8 hours 39 minutes after the closing of the premises. The fire in each case, therefore, must have been in existence at the time of the closing of the premises. If there were means in existence, as it was stated there were, and which he believed to be the fact, of preventing the present enormous fire waste, and if they were advocated by the Insurance Companies, it would mean a great minimising of fire waste.

MR. G. E. KEAY said he had dealt at greater length with Mr. Jordan's point in the fuller edition of the Essay.

On the motion of SIR SAMPSON SLADEN a hearty vote of thanks was accorded to Mr. Keay for his paper.

MR. KEAY, in reply, said the origin of the present meeting went back well over one hundred years to Dr. Fothergill. For some reason or other, Dr. Fothergill had been particularly interested in the problem of fire waste. After all those long years his memory was revived that night. If in some modest way he had helped to develop the ideas which Dr. Fothergill had had, and to preserve his memory, he was more than satisfied.

A vote of thanks to the Chairman concluded the meeting.

OBITUARY.

CAMPBELL PATRICK OGILVIE.—Mr. Campbell P. Ogilvie, who died on May 22nd, at the age of 73, was elected a Fellow of the Society in 1891. In 1910 he read a paper entitled, "Argentina from a British Point of View," for which he received the Society's Silver medal. He frequently attended the Society's meetings and took part in the discussions.

Mr. Ogilvie was a keen student of fish life and acted for a time as honorary curator of the Yarmouth Museum. He was also a great traveller and frequently visited South America, where he was interested in railways and land development.

For many years he was a director of the Central Argentine Railway, the Primitiva Gas Company of Buenos Aires, and other South American Companies. He was also a director and, until recently, Deputy Chairman of the Powell Duffryn Steam Coal Company of South Wales, and he had large coal and iron interests in Russia. Mr. Ogilvie had a considerable knowledge of trees and timber, and was a Fellow of the Linnæan Society. He devoted a great deal of time and trouble to the attempt to revive the flax industry in this country, and he gave several lectures on the subject, including one delivered in Melbourne in 1914 before the British Association, of which he was an active member.

CORRESPONDENCE.

RECENT TENDENCIES IN AFRICAN NATIVE EDUCATION.

(See *Journal*, p. 657.)

May I call attention to the serious dangers involved in teaching the hundreds of African vernaculars or even *one lingua franca* of African origin?

As Major A. G. Church remarked, "the greatest gift that could be given to the Africans was the gift of the English language" (p. 671). There is no linguistic problem in the world comparable to that of Africa. To teach religion or any other subject in a language in which there is no literature and only expressions for material ideas would show a remarkable want of common sense. Vocal sounds associated with and suggestive of animal passions, tribal hatred and wars, etc., cannot be made to explain spiritual or intellectual ideas or to arouse religious emotion. The real difficulty is not the *African* dialects, but the *English* language, as presented to the "tens of thousands of little village or bush schools" (p. 660) by our printers, who continue to refuse to print either what we say, what we think, or what we mean.

Incidentally, we need the African native population to buy the goods made in Great Britain. It is impossible to train English commercial travellers in African dialects, and it is equally impossible to sell, to natives who cannot pronounce English, such objects as sea-wing (sewing) machines, On-a-toe, or Oh-not-oh (Onoto) pens!

On p. 663 we read "Free access to the sources of Western knowledge is indispensable to Africans." Books are the chief sources of knowledge. How can these sources be opened up by an education in vernaculars? It is desirable, says the author "that some *lingua franca* of African origin should be developed," that is to say, invented. Such a language would be incomprehensible in the "tens of thousands of little village or bush schools," and in the hands of "exceptional individuals with outstanding accomplishments" would prove an organ of conspiracy and rebellion against English or other European influences.

Given an English language which he can teach himself, in reasonable and logical printed characters, the native African will soon learn what interests him in the history of his own people, if such books are put into his hand.

Mr. Bernard Shaw writes: "The English have no respect for their language. They print it so abominably that no man can teach himself what it sounds like." German and Spanish are accessible to foreigners: English is not accessible even to Englishmen.

A. DEANE BUTCHER, F.R.S.A.

NOTES ON BOOKS.

SOIL CONDITIONS AND PLANT GROWTH, ONE OF THE ROTHAMSTED MONOGRAPHS ON AGRICULTURAL SCIENCE. By Sir E. J. Russell. With illustrations. Fifth Edition. London: Longmans, Green & Co. 18s. net.

In somewhat over 500 pages Sir John Russell gives a lucid and carefully exact abstract of agricultural views and theories from Theophrastus to the present time, and a mere list of the important books and memoirs to which reference is made covers 26 pages in small type (pp. 467-493). The first impression, after a light glance through the book, is a vague sense of dissatisfaction, which accords unpleasantly with the statement in the preface that "the mass of papers is too great to be read by any one person," a position which is undoubtedly true if we take the word "read" in its scholastic sense. Sir John Russell continues, in a vein of criticism, on the quality of certain recent or present-day papers, and says:—"Unfortunately, also, some are written in such a way that their meaning cannot always be clearly apprehended." (p. V). Remarks like this tend to create doubt as to the complete or unmixed success of that universal primary education which was initiated by the Act of 1870, but was subsequently taken out of the control of directly elected School Boards and placed under local authorities elected for general purposes.

The work under notice, like other volumes on kindred subjects by Sir John Russell, is notable for clear, concise and unmistakable diction, so that a sentence seldom requires a second glance. In Chapter I, "Historical and Introductory," is a full justification of de Saussure's position as a pioneer in accounting for carbon fixation in the plant's growth, and of Boussingault as an early tabulator of rotational statistics as bearing on carbon. From Bousingault's work, commenced about 1834, we are taken to the Lawes and Gilbert field experiments (p. 18), commenced at Rothamsted in 1843, and continued by various workers to the present time.

Notable features of interest are numerous in the work before us, but we may specially refer to the thorough consideration given to bacterial influences and toxins. On p. 394 we read of Pickering's far-reaching conjecture that every growing plant generates a toxin. In the three prece ling and two following pages are references to commentators on Pickering's views, and towards the end of p. 396 we pass on to the question of special bacterial toxins. After this we are led to Warington's tabulated estimates of drafts on the soil by standard crops (p. 401). In 1878 Warington published the first of his series of memoirs on nitrification, in which he advocates the view that nitrogen is mainly assimilated by plants when it is presented in the form of a nitrate (p. 24). Thus bacteria, by transforming the various compounds of nitrogen into nitrates, "are the real makers of plant food in the soil" (p. 27); still there is a lack of evidence as to whether bacteria in soil exercise any direct influence for good or evil on plant growth; but indirectly the influence of the minute bacterium may be of high importance in many aspects. Bacterial action seems often to lead to considerable loss of nitrogen, especially in the case of wet, peaty, rich or highly manured areas, much nitrogen being evolved in the gaseous state, and at other times nitrates partly give place to nitrites, which Nagaoka regards as "poisonous" (pp. 262-263 and *c.f.* p. 75). Serious agricultural students and others wishing for a very full, masterly and lucid summary of soil and growth research during the last 50 years, with a study as to the bearings of previous work, also abundant references, can find nothing better than the work under notice

JOURNAL OF THE ROYAL SOCIETY OF ARTS

No. 3892

VOL. LXXV.

FRIDAY, JUNE 24th, 1927.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C.(2.)

NOTICES.

POSTPONEMENT OF ANNUAL GENERAL MEETING.

Owing to the eclipse of the sun on June 29th, the One-hundred-and-seventy-third Annual General Meeting, for the purpose of receiving the Council's Report and the Financial Statement for 1926, for the revision of the Bye-laws, and also for the election of Officers and new Fellows, has been postponed, by order of the Chairman of the Council, to Wednesday, July 6th, at 4 p.m.

GEORGE KENNETH MENZIES,

Secretary.

FUND FOR THE PRESERVATION OF ANCIENT COTTAGES.

THIRD LIST OF SUBSCRIPTIONS.†

	£	s.	d.
Amount previously acknowledged (of which £929 4s. 6d. was received through the Carpenters' Company)...	3,621	8	0
James H. Hyde, Esq. (in addition to £25 previously subscribed) ...	500	0	0
Boies Penrose, Esq. 2nd (\$500) ...	100	0	0
Miss Dulcie L. Smith ...	100	0	0
*The Guild of St. George ...	20	0	0
Francis H. Horton, Esq. ...	10	10	0
"Kingswood" ..	10	0	0
Sir John Ramsden, Bt. ...	10	0	0
Miss Agnes B. Warburg ...	10	0	0
Sir Edmund Gosse, C.B., LL.D., Litt.D. ...	5	5	0
Sir Frank Warner, K.B.E. ...	5	5	0

† The first and second lists were published in the *Journals* of April 8th and May 20, 1927.

	£	s.	d.
The Rt. Hon. Viscount Clifden, D.L.	5	0	0
Mrs. E. B. Gallimore	5	0	0
Miss Edith Hammond	5	0	0
C. M. Powell, Esq.	5	0	0
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Gilbert Taylor, Esq.	3	3	0
The John Sumner Trust	3	3	0
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W. J. Beavan, Esq.	2	2	0
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*G. T. Pilcher, Esq.	2	2	0
Archibald G. B. Russell, Esq. (<i>Lancaster Herald</i>) ...	2	2	0
Rt. Hon. Sir. Leslie Scott, K.C., M.P.	2	2	0
William Smith, Esq.	2	2	0
Ronald Vinson, Esq.	2	2	0
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The Rt. Hon. Lord Glentamar	10	0	0
The Rt. Hon. The Lord Mayor and Lady Mayoress	5	5	0
	15	5	0

Total	4501	7	0
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* Annual subscription.

COUNCIL.

A meeting of the Council was held on Monday, June 13th. Present :— Mr. Alan A. Campbell Swinton, F.R.S., in the Chair ; Sir Charles H. Armstrong ; Sir Frank Baines, C.V.O., C.B.E. ; Sir Charles Stuart Bayley, G.C.I.E., K.C.S.I. ; Captain Sir Arthur Clarke, K.B.E. ; Sir William Henry Davison, K.B.E., D.L., M.P. ; Peter MacIntyre Evans, M.A., LL.D. ; Sir Edward A. Gait, K.C.S.I., C.I.E. ; Rear-Admiral James de Courcy Hamilton, M.V.O. ; Sir Arthur Holbrook, K.B.E., M.P. ; Sir Herbert Jackson, K.B.E., F.R.S. ; Major Sir Humphrey Leggett, R.E., D.S.O. ; Sir Philip Magnus, Bt. ; Sir Reginald A. Mant, K.C.I.E., C.S.I. ; Sir Charles C. McLeod, Bt. ; Sir Richard Redmayne, K.C.B. ; Mr. Carmichael Thomas ; Professor J. M. Thomson, F.R.S. ; Dr. J. Augustus Voelcker, M.A., Ph.D. ; Sir Frank Warner, K.B.E., and Sir A. T. Wilson, K.C.I.E., C.S.I., C.M.G., D.S.O., with Mr. G. K. Menzies, M.A. (Secretary), and Mr. W. Perry, B.A. (Assistant-Secretary).

A letter from the President was read, signifying His Royal Highness's approval of the award of the Society's Albert Medal for the current year (*see page 763 below*).

The balloting list for the new Council was completed.

The draft report of the Council for the year 1926-27 was considered and approved for submission to the Annual General Meeting.

A report from the judges appointed to consider the entries submitted for the Thomas Gray Memorial Prize of £50 for an invention in aid of the Science of Navigation was approved. (*See page 763 below.*)

The revision of the Bye-Laws was completed and the Bye-Laws, as amended, were ordered to be submitted to the annual General Meeting.

The approximate number of entries for the Annual Competition of Industrial designs was reported.

The amount to date of the Fund for the Preservation of Ancient Cottages was reported. This includes recent donations of 500 guineas from Mr. James H. Hyde, £100 from Mr. Boies Penrose, £100 from Miss Dulcie L. Smith and an annual subscription of £20 from the Guild of St. George.

Courses of lectures and papers for the next session were considered.

A quantity of financial and formal business was transacted.

THE SOCIETY'S ALBERT MEDAL.

The Albert Medal of the Society for the current year has been awarded by the Council, with the approval of the President, H.R.H. the Duke of Connaught, to Sir Aston Webb, G.C.V.O., C.B., P.R.A., 1919-24, P.R.I.B.A., 1902-4, F.S.A., LL.D., "for distinguished services to Architecture."

Amongst his works may be mentioned the new façade to Buckingham Palace and the architectural surroundings of the National Memorial to Queen Victoria; the Admiralty Arch, Charing Cross; the completion of the Victoria and Albert Museum; the Britannia Royal Naval College, Dartmouth; the Royal College of Science, Dublin; the Imperial College of Science and Technology, South Kensington, and many other public and private buildings.

The Medal was founded in 1863, as a memorial to Prince Albert, for eighteen years President of the Society, and is awarded each year "for distinguished merit in promoting Arts, Manufactures and Commerce."

THOMAS GRAY MEMORIAL PRIZE FOR AN INVENTION.

Under the Thomas Gray Memorial Trust the Council of the Royal Society of Arts offered a prize of £50 to any person "who may bring to their notice a valuable improvement in the Science or practice of Navigation proposed or invented by himself in the year 1926 or in the years 1921-5 inclusive."

The following judges were appointed:—Rear-Admiral H. P. Douglas, C.M.G., Hydrographer to the Navy, Captain W. Ellery, Mercantile Marine Department, Board of Trade, and Captain A. H. Ryley, Trinity House. Thirteen inventions were submitted.

On the unanimous recommendation of the Judges the prize has been awarded to Mr. H. B. Goodwin, F.R.A.S., formerly Examiner in Navigation and Nautical Astronomy under H.M. Board of Education, for various works in connexion with Azimuth Tables.

PROCEEDINGS OF THE SOCIETY.

INDIAN SECTION.

FRIDAY, MAY 6TH, 1927.

SIR EDWARD A. GAIT, K.C.S.I., C.I.E., Member of the India Council and Chairman of the Indian Section, in the Chair.

THE CHAIRMAN said that everyone who had been in Assam knew Mr. Allen by reputation at least, if not personally, but for the benefit of those who had not been there he would say that Mr. Allen enjoyed an experience unique amongst Indian civilians until recent times by having remained faithful to the Province of Assam throughout his service. He went out in 1893, and had only recently retired, and had held the post of Assistant Commissioner, Deputy-Commissioner and Commissioner, and various posts, including that of Chief Secretary. He had also been in charge of the Assam Census at headquarters in 1901, and had revised the Provincial Gazetteer. There was no one better qualified to speak about the Province in which he had served so long.

The following paper was then read :—

ASSAM.

By B. C. ALLEN, C.S.I.,

late Commissioner, Assam Valley Division.

It is impossible to describe a province within the time at my disposal and the limits of your patience. I tried and found that it could not be done. And so I have confined myself to the events of recent years and to an attempt to convey to you some of the charm that hangs about Assam—that land of witchcraft. Those who desire a more ordered presentment of solid facts I would refer to the article on Assam in the Gazetteer of India. It is quite a good article. I wrote most of it myself.

“ It is not the large flat solitudes nor the cold craggy magnificence of ice fields and snowcapped peaks of the North West that first touch the chords of memory of the shelved and antiquated Anglo-Indian official. Rather it is the butterflies and the birds, the wild beauty of Bhutan or the deep silent tiger-haunted forests and savannahs of the mystical valley of the Brahmaputra.” These are not the words of an Assamese official bemused with enthusiasm for his province. They were uttered fifteen years ago in this very room by that eminent surveyor, Sir Thomas Holdich. If, in the course of the next few minutes, you are tempted to think that my colours are too bright, remember that I can call as witness an officer of world-wide experience, who owes no special loyalties to the Cinderella of the Indian Empire.

Take a lump of dough, press down into it the two forefingers and the thumb of the left hand, keeping them well spaced apart, and you will have a very fair replica of Assam. The province consists of the Assam Valley, the Surma Valley, and the intervening range of hills, the hills to the south and east which link us up with Burma and the native states of Manipur. Two valleys and some ranges of hills, that sounds a small affair, but as a matter of fact, the area is about the same as that of England and Wales.

The Assam Valley is what is known in the Highlands as a corrie, for it is surrounded on three sides by hills. But it is a corrie of colossal size. It stretches as far as from Dover to Edinburgh, has an average width of about 50 miles, and some of the hills that shut it in are over 20,000 feet in height. .

Down the centre of this majestic valley flows the Brahmaputra, a river which still retains some of the charm and attraction which belong to the unknown. For though it is certain that it is identical with the Tsanpo of Tibet, no civilized man has ever followed its entire course through the Himalayas. Where it leaves the hills it is known as the Dihang, and it is only after the Luhit has joined it from the east that it is styled the Brahmaputra. Near Sadiya the river is of extraordinary beauty. Wide enough to be like a narrow loch, the view on three sides is bounded by mountains whose snowy tops in winter gleam brightly in the sun. Further west it stretches out over its sandy strath, but throughout almost the whole of its course the hills are visible, on a clear day, generally on either side. The immediate foreground, as a rule, is flat, but this detracts little from its majesty. In the rainy season I have known it so wide that on a stormy morning neither bank could be seen from the steamer's deck, though we were hundreds of miles up-stream from the sea. If you travel at that time, as I have often done, in a steamer of but modest size, you acquire a very wholesome respect for the river's power. When evening falls you anchor in the lee of some small sandbank and watch the enormous flood sweeping along carrying trees and huge masses of reeds and grass upon its bosom. The bank is possibly a mile or more away, low rain clouds shut in the horizon, and you hope that they will not discharge a sudden squall which might upset your rather cranky craft. This is no impossible contingency, for only a few years ago one of the large river-steamers was blown over with dreadful loss of life.

Near the river the land as a rule is low and is covered with reed jungle, much of which has in recent years been taken up by hardy immigrants from Bengal, who are trained to snatch a living from places which an up-countryman would consider to be quite unfit for human habitation. Further back the level rises and there are wide plains covered with rice, and dotted over with villages buried in clumps of bamboo and fruit trees, with tea gardens or forests stretching, often for miles, over land which is too high for transplanted rice. Near the Himalayas there are grassy plains, the home of the partridge and the florican.

But the great glory of Assam is its mountains and its rivers. Over the Assam

range one can travel: the Himalayas offer the continual temptation of the unexplored and the unknown. During the winter the hill tribes come down, Bhutias, Tibetans from Towang, Akas, Daflas, Miris, Abors, Mishmis, and so on round the eastern end of the valley through Khamptis and Singphos, and the independent head hunting Nagas, till we reach the administered Nagas of the Assam range. Curious folk are they, who might have walked straight from the stage of the pantomime or a fancy dress ball at Covent Garden. Decent people for the most part but absolutely independent. They know that a strong government, whether our own or that of the Ahoms in the zenith of their power, can follow them into their rocky fastnesses. But they also know that this is a very costly and a very difficult proceeding, that there is no possibility of getting any compensating advantage, and that no Government will embark on such an unsatisfactory undertaking unless driven to it by the severest provocation. In time, no doubt, we shall be compelled to occupy the unadministered territory between Assam and Burma. But successive Secretaries of State have rightly shrunk from adventures north of the Brahmaputra. The tribes occasionally give trouble in the plains, but if you push your frontier into the hills you will have trouble there, and the further north you go the greater will your difficulties be.

Through the Himalayas a number of glorious rivers force their way to join the Brahmaputra. In the hills these rivers come foaming down in furious rapids, or sweeping silently but relentlessly along deep reaches between cliffs clothed in thick vegetation if there is so much as a cranny in the rock to give shelter to a seed. When they reach the plain they spread out over stony bottoms where the mahseer lie, and one at any rate intersects a game reserve. Here you may see wild buffalo, bison, deer and pig as you fish, or come across a tiger taking his evening drink, while in the recesses of the forest Government is once more accumulating a fine stock of that interesting beast, the great Ind'an Rhinoceros.

I hope that I shall not weary you, but so much of India is so ugly (could anything be duller and flatter than the Gangetic plain between Calcutta and Delhi?), that I can't help trying to get across to you the charm of 'the mystical valley of the Brahmaputra.' Travel up with me by road, then, if you will. You leave Gauhati and drive seven miles across a plain golden with rice stubble, and shut in on every side with hills. At the seventh mile you enter the hills themselves, hills covered with every form of vegetation. After a few miles you swing to the east, cross an outlying range and drop down to the valley again, travelling along through rice fields with the mountains close on your right hand. And so on through patches of jungle and forest, wide plains of rice, an occasional tea garden, an occasional river, till you come to the small town of Nowgong. Thence you head up towards the Brahmaputra, but before you reach it you turn again to the east, through hills and at the foot of hills, till you reach a great swamp lying between the road and the river, where buffalo and deer and

rhino can breed in peace. And so on with the gardens beginning to appear on the high ground at the foot of the Mikir hills, till you cross the Dhansiri and the mountains drop away almost out of sight to the south. On and on through tea gardens and villages, past Jorhat with mountains visible both to the north and south on a clear day, past Sibsagar, with its temples on the bank of a huge tank nearly two miles in circumference, till, after crossing more rivers, passing more villages, tea gardens and forests, you finally arrive at Dibrugarh, and look out across the stately flood of the Brahmaputra, to the blue mountains ten or so miles away.

The Surma Valley is less interesting. It is wider, flatter, more densely peopled, its rivers are smaller and more sluggish, its opportunities for sport less good. But were it not for their great rival across the Assam range, northern Sylhet and Cachar would be thought beautiful enough, while Manipur and the Lushai Hills to the south are full of charm. And here, lest you may think me too much of an enthusiast let me quote a former Chief Commissioner of Assam, Sir Bampfylde Fuller. He is describing the journey from the Sylhet border up the steep scarp of the Khasi Hills.

"Before us the stream, now become a torrent, rushed with clear cool water down a rocky bed. Beyond the stream our view was closed by a wall of long grass. Behind us rose the cliffs, dark blue, scarred in places by bare precipices down which tumbled a lacework of waterfalls, in places dense with vegetation. The rain ceased; we climbed the scarp by a steep, winding path, discovering that what seemed thickets of jungle, were really hillside gardens of oranges, betel, palm, pepper and bread fruit trees. As we mounted the cliff side the stifling heat of the plain fell away below us, and when at last we stood on the summit, refreshed by a cool breeze that surged with the noise of a hundred waterfalls, we understood the imagery of the Delectable Mountains."

HISTORY.

I have no time to refer to the history of Assam before it passed under British rule. There is an excellent account in the Imperial Gazetteer, written by our Chairman, and an admirable History of Assam from the same hand. The valley of the Brahmaputra was one of the passes by which successive waves of immigrants entered India from the east. There were powerful kings in Kamarupa a thousand years ago, Hindu by religion, but probably of semi-Mongolian race. In the 13th century A.D., the valley was entered by the Ahoms, a Shan tribe, who gradually subdued the whole of it as far as the Manas. Their waning power was crushed by the horrors of the Burmese invasion, and in 1826 the Company, after expelling the Burmese, assumed control. In prehistoric times the Surma valley was probably ruled by Rajas of the Bodo race. Sylhet north of the Kushiara river was at one time divided into three small states Jaintia, Laur and Gaur. South of the river the Raja of Tippera was the ruling Chief. Gaur was conquered by the Muhammadans in the

15th century and Laur submitted to the Emperor Akbar. This portion of the district passed to the British with the rest of Bengal in 1765. Cachar retained its independence till 1832 when the Raja died without heirs. The Raja of Jaintia was deposed in 1835 for complicity in the sacrifice of British subjects.

Difficulty was experienced in governing from Bengal so remote and inaccessible a country, and in 1874 it was formed into a separate province. The officials, other than the military civilians, served on deputation from other provinces in India, and there were no self-contained cadres. In 1905 Assam was incorporated with Eastern Bengal to form a new province which came to an untimely end in 1912. It is now a governor's province, with members of council, ministers, a local legislature and a self-contained commission. But it contains certain seeds of weakness. There is no community of interest between the Assamese and the people of Sylhet, some of whom for sentimental rather than practical reasons, have demanded reunion with Bengal. This request was supported by Assamese politicians, who found in the Sylhetis formidable rivals, and who believed that much of the money spent in that district was raised in the valley of the Brahmaputra. With the indifference to hard facts frequently found in those who have been newly invested with political power, they demanded that the system of government should remain unaltered, though that system was already exceedingly top-heavy and expensive for so small a province. This is one defect of the present government. Another is the size of the official cadres, which are almost too small for healthy competition and development. But, though these may be defects, their removal would be dearly purchased at the price of amalgamation with a province which has hardly any points of contact, cultural, historical or racial, with Assam.

During the last hundred years the history of Assam has, on the whole, been one of peaceful progress. In 1829, the Khasis suddenly rose and massacred two sapper officers and most of their following. This was the signal for a revolt, which was only subdued after much guerilla fighting, but the Khasis have since become some of the most loyal and most attractive of His Majesty's subjects in the east. In 1869, the Garos were pacified by posting a British officer in the interior of the hills. In earlier times they were looked on as confirmed head hunters and raids upon the plains were not uncommon. All this has stopped, and crime in the hills is rare. The Nagas, who live in the eastern end of the Assam range, proved much more difficult opponents. Repeated and continuous raids made the occupation of their hills imperative. The first district officer returned unscathed. Of the next three, two were ambushed and killed, and the third met his death at the hands of his own sentry. Since then the British district has been comparatively free from violent crime, though head hunting and the burning of villages still go on merrily beyond the border.

On the frontier there has from time to time been trouble, but the toll of European lives has on the whole been small. In 1839 Colonel White, the

Political Agent at Sadiya was killed and eighty others killed or wounded. Major Boyd, the Deputy Commissioner of Cachar died of injuries received in disturbance in the Cachar Hills in 1882. In 1890, Capt. Brown, the Political Officer of the North Lushai Hills, was murdered by Lushais, and in 1891 occurred the famous outbreak at Manipur, when the Chief Commissioner, Mr. Quinton, with his Personal Assistant, the Political Agent and the O.C., the escort, were beheaded in the palace. Twenty years were to elapse before the frontier claimed other European victims. These were Mr. Williamson, the political agent at Sadiya, and Dr. Gregorson, who, taking at their face value the invitations of the Abors, entered their hills with a considerable party of coolies, and servants, nearly all of whom were massacred with their leaders.

For generations, Assam proper was almost entirely free from political agitation. Commerce was for the most part in the hands of enterprising Marwari merchants: the Bengali dominated the bar and filled many government appointments, and the Assamese needed all the help that Government could give them to hold their own against these keen competitors. Officers serving in Eastern Bengal after the partition, as with most inadequate resources they waged an unequal fight against widespread civil commotion, looked with longing eyes on the untroubled calm of their old province. This happy condition of affairs continued till 1920. The reforms were accepted in the Assam Valley, the recognized leader of the Assamese readily agreed to serve as minister, the common people were indifferent, the intelligent Bengali community estopped from causing trouble in a country which was not their own, even had they wished to do so. Two misguided men were enough to stir up the valley and bring it to the side of Mr. Gandhi. Government pushed forbearance almost to the limit, but when it acted, acted with effect. The leaders were prosecuted, and convicted, though the doors of the jail at all times stood open to those who would abjure their revolutionary doctrines. One of the weapons of the Swarajists was the withholding of supplies from Europeans, and the people were organized for a no rent campaign. Under the ordinary procedure arrears are realized from those who will not pay, first by the sale of moveables and then, if that proves insufficient, by sale of the land itself. 'Have no fear,' the agitators said, 'no one will bid at the auctions, so that we shall retain our goods and lands and keep the money we ought to pay as revenue.' But they had overlooked the existence of a section of the law which empowers an officer, at his discretion, to remit the arrears and to resume the land. The mere threat of employing this section was enough, and land revenue flowed in at a pace even above the normal. Officers who for years had lived on terms of friendliness with the Assamese were astonished and distressed at this change in the demeanour of the people. But the reason was not far to seek. They had been told that Gandhi was a god. They had been told that when this god came to reign over them, land revenue would be reduced to one-fourth of the existing demand, that forest dues and forest restrictions would be abolished, and in ears which would receive the

news with pleasure, it was whispered that opium could once more be grown and spirits distilled without fear of an excise department. Small wonder that a simple people should turn to a ruler who brought such blessings in his hand. They were misled, but many of them soon repented of their folly. I was camping once in a remote village, and reproved the people, then friendly as ever, for having followed strange gods. "Sahib," they said, "the babu log told us that Gandhi was Raja, and we believed them. Now that we know once more that you are Raja, of course we shall obey you. He who is Raja his subjects are we." "*Je Raja tahar proja*," were the words they used, and they represent, I beg leave to think, the political philosophy of many million Orientals.

Fear of communal tension served as a check on Hindu swarajist activities in the Surma Valley. But an immense amount of misery was caused by a movement which led thousands of garden coolies to sell all that they had at knock-out prices, and start on the long and weary trek back to the villages which they had left to seek a fuller life in Assam. The talk of swaraj even spread a little way amongst the wild tribes on the frontier. To encourage unrest amongst people of this kind is the most reckless folly, yet I noticed in the report of the last meeting of the Ind'an National Congress a reference to work amongst Assamese hill tribes. This meeting was held at Gauhati. Ten years ago the suggestion that the Congress pandal might be erected in Assam would have been dismissed as beyond the bounds of probability. The incident shows the distance to which Assam has advanced along the path of politics.

Though the agitators were active in the valley, the Legislature was more reasonable than in the neighbouring province of Bengal. Even the swarajists abstained from adopting an entirely obstructive programme, and the formation of a strong independent party rendered the working of the reforms quite feasible. It is permissible to doubt whether the benefits derived from the new system of government are commensurate with the heavy increase in expenditure it entails. One of the most intelligent of the non-official Bengalis in Assam had no illusions on the subject. A democrat might say that he was prejudiced, as he was ineligible for office, but his point was clear. The old government, with which also he had no concern, was not a bad one. The new one was much more expensive and no better. The speaker was a very orthodox Hindu, and though his manner was always courteous and correct, I should imagine that he did not like the English. His testimony in favour of the old regime is, therefore, entitled to consideration. But whatever one may think of the system, and however much one may regret the foolish swarajist outbreak amongst our old friends the Assamese, it is something that those elected to the Council should have tried to carry on.

ASSAM IN THE GREAT WAR.

Assam is not a military recruiting ground, but in spite of this it made some contribution to the Great War. 174 of the civil officers were spared for military

duty. The I.C.S. has a cadre of only 43, and under the orders of the Secretary of State, no Indian Civilian might leave India for any theatre of war without his express permission. Twenty-two joined the army for shorter or longer periods, 2 of whom were killed. The highest mortality was amongst the regular officers serving with the military police battalions. Fifteen went, one third of whom were killed, and their places were taken by the wreckage of the war. 278 non-official members of the Volunteer Corps joined the Indian Army Reserve of Officers, the regular forces or the Labour Corps. The military police battalions served as training grounds for the regular army, and over 3,000 officers and men were drafted to fighting units. Manipur and the three large hill districts sent labour corps 2,000 strong to France, the Garo hills sent 500, and Sylhet 1,000 to Mesopotamia.

Many of these hillsmen had never so much as seen a railway train before they started. Yet they settled down quite happily in France and fitted into their old simple haunts just as easily on their return. The Nagas caused quite a sensation in their journey across India. At each halt all dogs in sight were killed and eaten and at one place it is said a dhobi's donkey added substance to the meal. The Indian staff were terrified at these naked men, armed with their spears and axes, and messages flashed down the line warning their friends to send their families away.

The war took its toll even from the most unlikely places. In 1919, I was camping in forests which seemed incredibly remote from Europe. In the evening the villagers squatted round the camp fire, with the light flickering on their faces and lighting up the tree trunks which loomed in the darkness like the pillars of some huge cathedral. And they told us how some of their men had gone, and how those who had returned had told them a little of the war, "but only a little, sahib, because there was an order, and what a curious war it was. How men would be gathered together and a box would arrive and when the box was opened men died." That was the Mikir's description of a bursting shell. The jungle folk took things very much for granted. The first railway tunnel was an alarming experience, but once you have swallowed a railway train, you can manage an ocean going steamer and an aeroplane. Sea sickness was a disease which it was held only attacked 'black men,' and those who crossed in the monsoon certainly suffered terribly.

RELIGION.

Of the 8 million people in the province, 55 per cent. are Hindus, 28 per cent. Muhammadans, and 16 per cent. adhere to those primitive forms of belief known as animistic. The bulk of the Muhammadan population is in the Surma Valley and in upper Assam there are comparatively few.

Assam was originally a stronghold of the Saktist form of Hinduism and the temple at Kamakhya is a noted place of pilgrimage. The shrine covers Sati's organs of generation which fell there when her body was lopped in pieces by

Vishnu. It is situated on the top of a rocky hill about 600 feet in height, whence a glorious view can be obtained on a clear day. To the south the Khasi Hills descend almost to the river; immediately below the mighty Brahmaputra flows between the rocky hills which shut it in on either side; to the north the plain, dotted with outliers from the Assam range, stretches away to the blue mountains of Bhutan. East and West the river spreads out like a great inlet of the sea till it disappears in the horizon. Nothing could be more striking than the contrast between the natural beauties of the scene and the squalid surroundings of the temple. It was erected to exalt and magnify impulses which, though essential to the perpetuation of the race, have enough natural vitality to need no stimulation or encouragement from religion. And for personified desire blood is considered to be the most appropriate offering. The finest sacrifice of all was man, and in the 16th century, when the temple was rebuilt, the heads of 140 men were offered to the goddess.

But repulsive though the temple is with its obscene carvings and its dripping victims, this is not the characteristic form of Hinduism in Assam. In the 16th century, the milder doctrines of Vaishnavism were preached by Sankar Deb and were adopted by most of the Assamese. The great centre of Vaishnavism is to be found in the Majuli, a huge island formed by a change in the course of the Brahmaputra in the Sibsagar district. Here there are a number of sattras or monasteries, presided over by men who still are held in the greatest reverence by the villagers. Situated in a tract which recalls the simplicities of 50 years ago, some of these sattras, with their quadrangles and fish ponds, suggest the peace and conservatism of Matthew Arnold's Oxford. When Lord Chelmsford visited Assam in 1920, the principal abbots, men of the greatest dignity and charm of manner, asked to be allowed to present him with an address. The nationalist lawyers did all that they could to get the meeting boycotted, but the authority of the abbots and the desire to see the Viceroy made opposition futile. The villagers assembled in thousands round the great pandal in which the leading abbots, dressed in their robes of state, awaited the arrival of their distinguished guest. The wall opposite the dais was formed by a row of elephants standing side by side, and so great was the concourse that it was with difficulty that the Viceroy could make himself heard above the murmurs of the multitudes who had come to see him. The whole scene was so unusual, so spontaneous, so old-world, that Lord Chelmsford told the Secretary of State that it was one of the most impressive things that he had seen in India.

The Assam hills afford a most excellent field for missionary zeal, and the Welsh Presbyterian Mission has done sterling work especially amongst the Khasis and the Lushais. Of the former one-sixth and of the latter one-fourth are now Christians. A short time ago there was some discussion on the effect of missionary work in China. I have no desire to tread on dangerous ground. But even convinced evangelists would, I suppose, admit that there was risk in invading countries in which an old established religion held the field. We, for

instance, should hardly welcome an active and successful Hindu or Muhammadan mission in England. In the Assam hills there is no such obstacle. The rather vague and conflicting animistic beliefs have none of the solidarity or binding force of the old religions, and no one who has been brought into contact with them has anything but the highest praise for the Welsh missionaries. The Christian hillmen are the cleanest, the most prosperous, the best educated, the most reliable of their tribe. Amongst the Khasis, a very democratic people, there is no racial bar within the church, and Khasis have, I believe, presided over synods. It is, perhaps, a matter for regret that there are so many who wish to labour in this fertile vineyard. The Welsh Mission were the pioneers and are by far the strongest organization. But the Roman Catholics, prior to the war, were pursuing a very active policy. The capable and cultivated head of the mission and all his assistants were Germans, and were in due course interned. Their place was taken by Belgian priests, but the work of the mission received a certain check. There are also the Church of England, the Unitarians, and a curious American body known as the trumpet. One cannot but feel that it is rather hard on the Khasi, to ask them to choose between so many types of doctrine, and to the detached onlooker a competition for converts seems scarcely in accord with the principles that all the sects profess. The American Baptists have also worked amongst the Nagas, the Garos and in certain parts of the Assam Valley, but, on the whole, with less success.

REVENUE.

The principal heads of revenue are land revenue 105 lakhs, excise and opium 77 lakhs, income tax 24 lakhs, and stamps 20 lakhs.

The greater part of the land revenue comes from the former dominions of the Ahom rajas as most of Sylhet and Goalpara are permanently settled. In 1789 the collector of Sylhet, much against his will, settled an area of 2,100 square miles in a working season. Conscious, no doubt, of the glaring imperfections of his work, he caused most of the original documents to be destroyed. A revenue survey carried out between 1859 and 1865 is probably a most inaccurate record of the boundaries of the original estates. Settlement was made for the most part with the cultivators. There are over 50,000 separate properties, 22,000 of which pay a revenue of one rupee or less, the average being about $6\frac{1}{2}$ annas. After the war, Government proposed to make a survey and record of rights of the permanently settled area. The cost would, of course, be high, and the new legislative council considered that the undoubted advantages it would give would be too dearly bought. It is possible that they were not wrong.

Goalpara is the absolute converse of Sylhet ; the estates are few in number but enormous in size. It is doubtful whether they were ever really settled, and the peppercorn rents they pay are probably merely a nominal tribute demanded from the border chiefs. Government has, however, never contested the owners' title.

In the rest of Assam the ordinary principle is that the land-owner enjoys a heritable and transferable right, so long as the revenue is paid, but that the revenue is liable to adjustment at the end of each period of settlement. The amount of increase is limited, by rule, if I remember right, to a maximum of 100 per cent. in any given estate, and to 33 per cent. over the district as a whole.

Such enhancements as have recently been taken in the crown lands in Regent Street would leave an Assamese settlement officer speechless with amazement, but he is confronted with a practical problem. All his instincts urge him not to over-assess the cultivator. Yet if he pitches his demand too low, apart from the abstract injustice to the general taxpayer, he encourages the growth of middlemen, who appropriate a share of the produce of the land without giving anything in return either to the State or to the actual cultivator. In Cachar, where the rates of revenue are noticeably lower than in Assam, a very considerable proportion of the district is sublet. Till recently and for all I know at the present moment, advanced Indian politicians were all in favour of a permanent settlement, a policy directly opposed to the theories of their socialistic friends in England. Steps, unfortunately rather belated steps, have recently been taken to secure for the State suburban land likely to increase in value. But experience gained in Assam does not suggest that it will be to the advantage either of the State or the tenant farmer for the State to purchase the landlord's rights in Britain.

EXCISE.

Long before the arrival of the British, the Assamese were greatly addicted to the use of opium. We prohibited the growth of the poppy, and for many years pursued the policy of discouraging the habit by reducing the number of shops and steadily raising the price of the drug. Since the Great War, there has been a vigorous campaign against opium both in Europe and the East conducted for the most part by people who, like myself, have not the slightest wish to touch it. Horror of opium is inborn in the average Englishman, but I remember that in 1920 when I was dealing with the matter, I found to my surprise that the commission of 1893 were unable to make out a very convincing case against the drug, and that the same was true of a local commission appointed many years later in Assam. Still it is a bold government which will resist the demands of temperance reformers, and shops have been rationed, sale forbidden except to registered consumers and the price raised to a figure which presses very heavily on the opium eater. As a result (I quote from the Government resolution), "smuggling of Malwa opium continues; short weight and adulteration are now sources of greater profit than before to the dishonest vendor; cases of poppy cultivation on an extensive scale and of smuggling from distant countries such as Afghanistan and China have been detected." Government frankly admits that its policy must be pursued with the greatest caution, but it seems possible that it has already advanced further and faster

than the ordinary official who is brought into contact with the consuming classes would approve. Personally I cannot forget the repeated requests that I have received of recent years from members of the different forest tribes. "Sahib, can't you do something to bring down the price of opium?" And these requests were made not by wretched trembling creatures, who clearly needed to be protected against their own debased desires, but by decent folk who were to all seeming healthy enough. Assam is a country where wild ganja grows like a weed, and ganja is probably more deleterious than opium, where the poppy could in many places be cultivated with little risk of detection, where spirits can be distilled and rice beer brewed with the greatest ease. Excessive zeal in the cause of temperance can easily do more harm than good. In one direction, at any rate, Government seems to have pushed repression to the very margin of possibility. They have prohibited opium smoking in company. I have not a word to say in support of opium smoking, which is a very different thing from opium eating or drinking, but it is clear that you cannot prevent two brothers from smoking together in their home, or forest villagers from smoking together in the jungle unless public opinion is on your side. There are cases in which such a law may do good, but unless the public are behind it it can be disregarded as easily as the 20 mile speed limit here. Victorians like myself still have an uneasy feeling that it is not wise to teach the people to be lawbreakers. In the old days the right of vend of excisable articles was put up to auction. The idea gained ground that excessive prices were paid, and that lessees were driven to irregular practices in order to recoup their losses. Now the maximum price is fixed and the lessee is selected, not without difficulty, from the large number of persons willing to pay the price. I say 'large' advisedly, for in one district alone there were nearly 4,000 tenders for less than 70 shops. The new system entails a loss of revenue; whether this loss is accompanied by anything which makes for temperance is not so certain. I express this doubt the more readily in that I was, I believe, the first person to call attention to the difference between the offers made at auction and the legitimate profits that could be reasonably expected. Theoretically the system of unrestricted auctions was not right, but here, as often, there may be conflict between theory and practice. Temperance, or rather not temperance but total abstinence, is a large and heavy plank in the platform of political India. Reformers might well ponder the words of Dr. Crichton Miller: "Much harm is done in every department of human behaviour by the propagandism of those who are immune from temptation. If I happen to dislike alcohol in every shape and form, I should recognize that I am thereby unfitted to preach temperance to the intemperate. If I am temperamentally too cautious to risk my money in betting, I should refrain from taking part in an anti-gambling crusade"

Ganja is generally thought to be more harmful than opium, but if excise ganja is withheld, wild ganja can be easily obtained. Country spirit of a wholesome kind is sold at licensed shops. If this were denied to the drinking classes,

they would have little difficulty in obtaining home-brewed liquor, which is consumed in large quantities by the animistic tribes.

FORESTS.

The reserved forests of the Province cover an area of nearly 6,000 square miles. The net profits of the Forest Department amounted to nearly 15 lakhs in 1925-6. This was a great advance on the average for the five years ending 1924-25, which was less than 7 lakhs. The most valuable property are the sal forests in Goalpara. The evergreen forests probably contain large areas which could more profitably be handed over to the cultivator as population increases. In the hills, on the other hand, Jhum cultivation is a most wasteful practice, and if the difficulties of planting in a semi-tropical climate could be overcome, afforestation is probably the most useful purpose to which the foothills could be put. The great development of rubber planting in the East was anticipated by the Assam Government by nearly 20 years. The rubber industry has had its ups and downs, but it has produced millions of pounds for capital and labour. The government rubber plantation sometimes covered working expenses, but for some years past has not paid to tap and the Conservator reports that it is not worth retaining. The trees were *ficus elastica*, the wild rubber of Assam, and not *Hevea brasiliensis*. I do not wish to press the argument too far. There are, of course, explanations of the difference. But socialists might note that in this case there has been a certain difference between the results of Government and private enterprise.

TEA.

To the man in the street the name Assam suggests before anything else the one word tea. The history of that industry, like that of rubber, is one which might be profitably studied by a socialist. Of the thousands of planters who have come out to India, I doubt whether one had any wish to produce for use and not for profit. All of them, I feel sure, were inspired by that deplorable motive, the desire for personal gain. Yet even a socialist would probably admit that these misguided men have done more for the development and prosperity of Assam and its inhabitants than any other single force that has been operating there during the last hundred years. That tea grew wild in Assam was discovered in 1823 by a Mr. Robert Bruce, who was in the service of the Ahom Raja Chandra Kanta Singh. Twelve years later a committee set up by Government decided that the tea of Assam was the true tea of commerce. Mr. Bruce's brother a Mr. C. A. Bruce, was appointed Superintendent of the Government tea forest, and established a factory for the treatment of leaf plucked from the wild trees in the jungle. At that time it was thought that Assam tea was a degenerate variety of the Chinese plant, and seeds were therefore, brought from China and a plantation started. It was located near the junction of the Brahmaputra and the Kundil rivers, but as the plants did

badly in the porous soil, they were removed to Jaipur. In 1840, the estate was sold to the Assam Company which had been formed in the previous year with a capital of half a million. For the first ten years or more of its existence the Company did badly. And it is indeed, difficult to imagine how so large a capital could have been profitably employed in this remote and isolated country, destitute of markets, labour and supplies. In those days it must have been at least a six weeks journey from Calcutta to the headquarters of the Company. Only those who have lived on the outskirts of civilization can fully realize what such distances mean. By 1852 the Company had turned the corner, and for many years it has been one of the largest and strongest of the Assam concerns.

In 1858, the Jorhat Company was floated and the success enjoyed by these two undertakings led to the opening up of new gardens in all directions, to over-production and to the inevitable slump. In 1869, the industry began to improve, and there was a long period of reasonable prosperity. In the nineties, however, supply once more outstripped demand and the price of tea fell below the cost of production. A tea cess was imposed in 1903, the proceeds of which were used in pushing tea in foreign markets, and gradually demand caught up supply. During the war the industry was prosperous, but peace found the market overloaded with huge quantities of inferior tea held on behalf of Government. This, coupled with a sudden rise in the price of silver, which sent the rupee up to double its previous value, produced a very serious crisis. In 1920, most of the companies made heavy losses, the weaker concerns had the greatest difficulty in obtaining accommodation, and at one time it seemed possible that thousands of coolies might be discharged from sheer inability to pay them. This ultimate disaster was averted, but I know of at least one case in which a small Indian owner paid his coolies in tea for lack of anything better. Seldom, however, has there been a more rapid change of fortune. To take a concrete case. Four prosperous companies with an aggregate capital of 1½ million sterling, made an aggregate loss in 1920 of £221,000. In the following year their profits amounted to £166,000, and this figure was largely exceeded in the next three years. These profits sound and are exceedingly attractive. But, as I have explained, tea, like other plantation industries, is subject to great vicissitudes. Many of the less fortunate gardens only do reasonably well in periods of prosperity, and you cannot often buy shares in the stronger companies at prices which yield a high return in the long run.

The gardens cover an area of over a million and a half acres, of which 413,000 acres are under tea. The labour force with their dependants amounts to nearly a million souls, most of whom have been brought at great expense from other parts of India. These people have come because it was difficult to earn a living in their own over-crowded villages, and in Assam they find an opportunity of rising from the ranks of a daily labourer to that of a peasant proprietor. In the Assam Valley alone nearly 300,000 acres of land are settled with ex-garden coolies.

The gardens give a great deal of employment to members of the middle class, a class which is sorely beset to find a living in modern India ; they offer a splendid market to the villagers for all the produce they can grow, and it can be safely said that had it not been for this invasion of exploiting capitalists, Upper Assam would have been little more developed at the present day than it was 50 years ago.

The old-fashioned tea-gardens were rather ugly things--enormous stretches of tea pruned and plucked down to bushes about $3\frac{1}{2}$ feet in height. During the present century the idea gained ground that it was not good for tea to be exposed to too much sun, and shade trees have been planted amongst the bushes. This has completely changed the aspect of the scene, and the dark green bushes with the light feathery trees above and often a wall of forest in the distance are now a far from unattractive sight. On every garden of any size are the bungalows of the European manager and his assistants, set in the midst of tennis lawns and gardens of flowering shrubs, and in close proximity are the factory buildings.

Tea, as most people know, is made from the bud and the leaves on the young shoot. After plucking it is left to wither, then rolled to allow the sap to escape, left to ferment, then fired and sorted through sieves into different qualities. Tea houses, as they are called, have recently been brought under the Factories Act. There were few healthier places on a garden for small children and nursing mothers than the withering, fermenting, and sorting sheds, and it is to be hoped that the extension of this Act will not have the effect of driving these poor creatures into the sun and rain during the monsoon. Taking them as a whole, the garden coolies are still in a very primitive stage of civilization. One of the objects of the enlightened employer is to raise their standard of comfort, and so induce them to work harder in order to satisfy their newly-found desires. It is not to anyone's advantage that a coolie should be content to exist in rather a mean and sorry fashion on the product of half a day's work. Recently there has been a very marked advance in the rates of wages paid, and these good wages will, I am sure, benefit not only the coolie but the industry.

OTHER INDUSTRIES.

Tea has been enormously successful in Assam, but there has been no great development of other capitalistic crops or industries. An attempt has been made to grow sugar cane and jute on the large scale, but these enterprises are still in the experimental stage. Indigo planting has, I believe, definitely failed. There are coal mines in the hills, to the south of Dibrugarh and Nazira, and coal is worked in the Garo and Khasi hills. There are oil wells at Digboi near Dibrugarh and at Badarpur in Cachar and lime quarries to the north of Sylhet. But considering the large area of mountains in the province the mineral wealth tapped up to date is disappointing. There are ten saw mills and seven oil mills, but their success is not sensational. Assam in fact has got an absolute

winner in tea, but does not seem able to do much with anything else. The Assamese themselves have little industrial or commercial aptitude. Sericulture and hand-weaving were flourishing cottage industries thirty years ago, but they are dying out, and it is yet to be seen whether Government will be able to stop their decline. Trade in the Assam Valley is for the most part in the hands of the astute Marwari merchants. Few Assamese have capital, and a good literary and moral education does not equip them to compete with people who for generations have followed the higgling of the market. For many years it has been the policy of Government to help the Assamese in their struggle with the more energetic foreigner, and it was this fact which made their adherence to the swarajist banner so surprising. This policy is, doubtless, still maintained, but it is difficult to convert a community of easy-going agriculturists into shrewd men of business.

OTHER IMMIGRATION.

Of recent years two other factors besides the tea industry have contributed to the peopling of the waste places of the Assam Valley. Pressure on the soil has driven the natives of the border districts of Bengal to move up to Assam. In Goalpara they now number 141,000, in Kamrup 42,000, and in Nowgong 55,000. They take up low land near the river, which the Assamese considered to be fit only for cold weather crops. Another colonizing factor are the Nepalese of whom there are 70,000 in the province. They start generally as woodcutters and graziers, and are not greatly liked either by the Assamese or the district staff. They are something of a nuisance, suffer severely from malaria, and the general feeling is that it would be better for them and everyone else if they stayed at home. Nothing can be nicer than the Gurkha under discipline, but discipline he requires. He gets it in his own country, whose authorities want to keep him. He prefers the freedom of the jungles of Assam, but I doubt if it is good for him.

PUBLIC HEALTH

Assam has rather a bad name for unhealthiness, but so far as the European population is concerned, there is little or no justification for the charge. It is entirely free from plague and did not suffer very severely from the influenza epidemic of 1919. Cholera, the most dramatic of oriental maladies, is often prevalent and caused over 19,000 deaths in 1924-25. Kala Azar is, however, the disease which is most closely associated with the province. It was reported as far back as 1869, but came into prominence in 1883. At first it was thought to be a form of malarial fever, then it was said to be Anchylostomiasis, but in 1896, Captain now Sir Leonard Rogers reverted to the original theory that it was a form of malarial fever which was so pernicious as to be capable of transmission from the sick to the healthy. This pronouncement brought into the arena Surgeon Captain Giles, the advocate of the anchylostomiasis theory, who

wrote in 1898 " Dr. Rogers, like a medical Alexander, cuts his Gordian knot by announcing that Assamese malaria is infectious. In this he places himself at variance with not only the scientific but the popular opinion of the entire world." Seldom has the scientific opinion of the entire world been more promptly and signally proved to be entirely wrong. Government has spared no pains to discover the carrier of this dreadful disease, but it baffles all enquiry. At one time the experiment was tried of burning infected villages, and moving the inhabitants to a new site, but this was a very expensive and unpopular measure, though it did seem to produce results. Fortunately Sir Leonard Rogers discovered that the injection of salts of antimony cured a large proportion of cases. The Department of Public Health is now on the look-out for the disease, and opens inoculation centres where it is prevalent. It is still a serious problem, and caused over 5,000 deaths in 1924-25. But this is nothing compared to the dreadful epidemics of the nineties, when no remedy was known. Kala Azar, when introduced into favourable conditions, burnt on like a slow fire which nothing could escape. In the Nowgong district over 30 per cent. of the indigenous population disappeared during the decade ending with 1901. Before a remedy was discovered hardly any one attacked recovered, though they took from three months to two years to die. Large tracts of land went out of cultivation, villages were abandoned and lapsed into jungle, and in one part of the district half the population disappeared.

COMMUNICATIONS.

Assam was for many years extraordinarily remote from other parts of India. The rivers were the only lines of through communication, and travelling by water was extremely slow. The journey down stream from Goalpara to Calcutta took from 25 to 30 days, and Goalpara is only on the borders of Assam. Up traffic must have been almost impossible for heavy boats during the rainy season. Captain Wilcox reported that in October, 1825, a fleet of commissariat boats had taken 25 days to cover 30 miles. This seems almost incredible, but I admit that I have steamed in the Gauhati reach for 2 or 3 hours and have then put back because I found that I had made no headway. In 1847 Government placed some steamers on the Brahmaputra, but they ran at uncertain intervals and did not proceed beyond Gauhati. The work was then undertaken by private companies, but it was not till 1883 that a daily service was established. When I joined the province ten years later communications were still far from easy. I had been ordered to report at a survey camp near the capital of Cachar. No one in Calcutta seemed to have any clear idea of how to get there, but I travelled by train to Goalundo and took steamer. I had to change steamers three times, each being smaller than the last, and ultimately reached a village from which a steamer started twice a week. I was not prepared to wait for that, so I put my belongings into a country boat and walked the last 17 miles along the bank. At that time there were barely one hundred miles of railway in

the province, and these were small local lines connecting the tea gardens of Jorhat and Dibrugarh and the Mangherita coal mines with the Brahmaputra. The journey from Calcutta to Dibrugarh took seven or eight days, the journey to Shillong took three or four. Now there are over 1,000 miles of railway in the province. Shillong is barely 24 hours and Dibrugarh less than two days from Calcutta.

The Assam Valley is well supplied with roads : in the Surma Valley they are not so numerous, as the low-level of the country makes construction difficult. The cost of metalling is prohibitive, and during the rainy season many of the roads are a sore trial to the traveller. The motor has revolutionised existence in planting Assam. Before its advent life in the gardens during the rains tended to become parochial. Now the effective area is so widened that the old practice of tennis open to all on certain days has had to be abandoned. From the railway the means of communication taper down to some of the most primitive lines of traffic in the world. Nothing could be worse than the average trans-frontier path and a cane ring sliding on a cane rope high above a raging torrent is a method of crossing a river to be used only by those who are entirely immune from attacks of giddiness. Even a civilized cane suspension bridge is quite an interesting sight. I can recall one in the Naga Hills. There were two large trees, one on either bank. A cane was fastened to almost every branch and the whole was plaited and woven together till it seemed to be almost a living bridge swinging across the river fifty or sixty feet below. Elsewhere in the hills I have travelled along the path of primitive man, i.e., the track made by the wild elephants through the forests and seen beside it one of those elephant dancing floors described in Kipling's *Jungle Book*. In the Khasi Hills I once was told that I could not take my pony any further. I replied that where a man could go a clever pony could, but when I found that the path suddenly went up a ladder, I owned that I was wrong.

THE HILL TRIBES.

I should like, if you can bear with me for two minutes more, to refer to the hill tribes of Assam. On the west are the Garós, living in low jungle-covered hills. Left to themselves they wear extraordinarily little clothing. A woman's dress is about 12 inches long, a man's is even less. But in spite of, or possibly because of this, their standards of respectability are very high. On the other hand, their Khasi sisters on the east wear a multitude of garments, and claim and have obtained the right to do exactly as they please. Persons who are shocked at the scantiness of modern female dress should note that in the Assam Hills the more clothes you wear the naughtier you are. The Garos live as a rule in tiny hamlets in the forest, and though they have their parlours on the ground, their bedrooms are prudently built in the branches of elephant-proof trees. The advantages of the custom seem very clear to travellers like myself, left to sleep on the ground floor and chance the visits of a maneater, who at that

time was very active in the neighbourhood. It is humiliating to feel that you have become potential food. The Khasis on the east inhabit a most delightful tableland about 5,000 feet above the sea. Here the capital of Assam has been built amongst rolling downs and pine woods, and as a result the hillmen have become extraordinarily prosperous. They are a most intelligent race, and a few years ago a Khasi won the Prem Chand Roy Chand scholarship, which is, I believe, almost as great a distinction as the Ireland or Hertford. The matriarchal system is still in force. Property belongs to the women, inheritance goes through her, and the children are hers. Anything a man earns before marriage belongs to his mother, and after marriage to his wife. Theoretically, in fact, he has no independent economic existence. Yet in practice the system works very well. The men are extremely jolly, the women, in spite of their privileged position, have lost none of their charm and are no more logical or masculine than their sisters in less feminist countries.

Further east again we come to the different tribes of Nagas. They are the most determined head hunters in Assam. The cutting off of an enemy's head is a fairly common incident on the frontier, but no other tribe has made such a speciality of the practice. The custom has reacted on their whole social system. It has compelled them to live in large fortified villages perched on hill tops like the towns in the south of France, and has produced a great variety of languages as a result of the restrictions on social intercourse. The British district has for many years been admirably administered. The Nagas are delightful children who make an irresistible appeal to the officers who work amongst them. But they are children who need a wise and firm as well as a loving mother. Beyond the frontier there are a succession of independent tribes, living in the tumbled mass of mountains that lie between Assam, Burma and China.

Have I been able to suggest to you something of the charm of the mystical valley of the Brahmaputra? Of the river flats yellow with mustard, where the partridges are calling from the jungle, of the marshes covered with duck and geese, of the grassy plains at the foot of the blue mountains that you may not enter, of the rivers clattering along over their rapids and swirling down their deep and silent reaches. And this is only the valley—what of the hills—the lower ranges covered with forest where you may meet all sorts of game from elephant to wild dog, the high plateau of the Khasis, the open rolling downs, the pine woods, the river valleys, the fresh wind-swept country like the Border country before the motor came to spoil it. And so on eastward to the serrated ranges of the Naga Hills where you can climb 10,000 feet to the small rock which forms the summit of Japvo, and look over range after range of mountains melting away into the blue distance. The Naga Hills, whence you can start, if Government so wills, into country which is entirely unexplored and is still represented by blank spaces on the map. What of the people, the wheat coloured Kalitas and Brahmans of Assam, spare men with high-bridged noses

and faces which often recall the pictures of the mediæval priest, the jovial Miris steering their canoes down foaming rapids, the sturdy Kacharis in their upland villages, the timid Mikirs in the depths of the forest, the tame hillmen from the south, the wild hillmen from the north, Bhutias with their wide cheerful faces, the savour of whose raiment rises up to heaven, Daflas with their fringes of bear skin attached to their cane caps, Apatanangs with their quaint tails of cane, Abors treacherous and fierce, Mishmis with cane hats in shape and size like the British helmet, and so on past tribes whose culture comes from Bu ma to the naked Nagas beyond the frontier.

If I have been unable to convey to you the attractions of a country such as this, it is I alone who am to blame, and not Assam.

DISCUSSION.

THE CHAIRMAN said he was sure everybody had listened with pleasure and profit to Mr. Allen's most interesting and instructive paper. His vivid description of Assam, of the lofty mountains in and adjoining it, its impetuous rivers, picturesque hill tribes and extensive forests in which the elephant, rhinoceros, bison and buffalo still roamed, made those who had never been to the country desire to go there, and caused an attack of nostalgia in one, at least, of its former residents. It was a most interesting province. There was no part of India where the establishment of the Pax Britannica had been so beneficial to the inhabitants. When, after expelling the Burmese about a century ago, this country reluctantly assumed the government of the country, the Assam Valley had been for years a prey to internecine wars, in the course of which extensive areas had been depopulated. Similarly, many of the hill tribes were addicted to head hunting, and each small community lived in constant dread of murderous attacks. As soon as peace and orderly government were established, the population, which was then very sparse, grew rapidly. There were no statistics to show the actual rate of increase during the first half century of British rule, but it certainly was greater than in the second half, when we know from the census statistics that the population doubled itself. It would have increased even more in the latter period but for widespread epidemics of *kala azar*, a deadly disease which had now been brought under control, thanks to Sir Leonard Rogers, to whose valuable discoveries India owed so much. The improvement in the material condition of the people of Assam had kept pace with the growth of the population. Next to a fertile soil, peace and good government, the most important factor had been the tea industry, and the lecturer had shown the various ways in which the development of that great industry had benefited different sections of the population. Christian missions had achieved remarkable success amongst some of the hill tribes, but they had comparatively few converts among Hindus and Muhammadans, an experience which was common to most parts of India. The achievements of missions, however, must not be judged solely by their proselytising results. In Assam they had studied many of the tribal languages and reduced them to writing, and throughout India they had done most wonderful educational work. They had instilled Christian ideals into the minds of many who still retained their own religion; and they had done a great deal to improve the standard of living and the general conditions of the people. The lecturer's testimony to the improvement noticeable amongst the Khasis who have embraced Christianity reminded him of a similar testimony

to the work done by Christian missionaries in Chota Nagpur, which had been given by an Indian friend of his who said, "The most careless observer can tell the house of a Christian convert of some years' standing from that of his non-Christian fellow tribesman by the greater cleanliness and orderliness of the Christian's home. The contrast will, we hope, help towards an appreciation of the achievements of the Christian missions in the noble work of civilising and educating the aborigines of Chota Nagpur." The lecturer had referred to the diversity of languages spoken in Assam, and, as a matter of fact, it was the most polyglot province in India. In addition to the numerous languages spoken by tea-garden coolies, Nepalese wood-cutters and others, no fewer than fifty-two indigenous languages were recorded in the last Census. Primitive man shed his languages even more readily than his religion, and in the open plains tribal languages had given way to other languages, mainly Assamese in the Northern, and Bengali in the Southern, Valley. It was chiefly in the hills and the adjacent submontane tracks that difficulties of communication, head hunting, and other obstacles to free intercourse, had enabled the tribal dialects to hold their own. It was impossible to deal with everything in the course of a short paper, but he was a little surprised to hear no mention of the terrible earthquakes from which Assam had so often suffered, the last of which occurred in 1897, shortly before his transfer from Assam. It was worst in the neighbourhood of Shillong, where he was stationed. Suddenly, without any preliminary warning, came a series of most violent shocks lasting for three or four minutes. Every masonry building in the place collapsed, the made-up portions of the road slipped down the hillsides, bridges were swept away and telegraph posts broken. They were cut off from communication with the outside world, and it was rumoured that Calcutta was also destroyed. It was some days before it was known that that was not the case, and that Shillong was in the centre of the disturbance.

SIR CHARLES STUART BAYLEY, G.C.I.E., K.C.S.I. (Member of Council), said that he, no doubt like the rest of the audience, had looked forward keenly to the prospect of hearing Assam described by a lecturer who knew the province thoroughly and of listening to the remarks of the Chairman who was the highest living authority on its history, and he was quite sure that the anticipation of all present had been amply fulfilled. He was well aware of the scantiness of his own qualification to say much on the subject. Perhaps the best claim which he could put forward was that his first acquaintance with Assam was made as long ago as 1880, when he acted for six months as Assistant Secretary to the Local Administration, and that it was his good fortune to return there for two short spells in 1908 and 1911-12 as head of the too short-lived Government of Eastern Bengal and Assam. Of each of these periods he treasured the happiest recollections. To the first of them he owed much of his subsequent official career, for he was lucky enough to receive excellent training at the hands of the Chief Commissioner, Sir Steuart Bayley, and of one of the best secretaries who ever served the Government of India, that versatile and accomplished scholar, Sir Charles Lyall. Small as was the value of his own work, he could claim to have set a good example socially by marrying the daughter of an Assam official of the old school, an example subsequently followed to the great benefit of the province by both the Chairman and the lecturer. Those far-off days were very bright, for life was made easy and pleasant for all by such men as Sir William Ward, Mr. Ridsdale, Captain Williamson, Sir James Buckingham, and very many other officials and planters, who had done first rate work in their respective spheres and had earned universal esteem and affection. The Assam of those days was a very different place from that which it had since become. There

were no railways, the steamers were slow and irregular, and even travelling by tonga was apt to be more exciting than speedy. When he returned nearly 30 years later many things had changed. Railways, regular daily steamers, motor-cars had made travelling easy. The Chief Commissionership had become part of the Lieutenant-Governorship of Eastern Bengal and Assam, organized by the capable and energetic hands of Sir Bampfylde Fuller and the sound and experienced guidance of Sir Lancelot Hare. The tea industry had grown enormously, coal-mines had been opened, oil wells were flowing. One thing, however, remained unaltered. Officials and non-officials alike were hospitable and kind and life was as happy as ever, though at the last it was clouded by the shadow of the impending dissolution of a province which, notwithstanding agitation which, the speaker believed, was mainly factitious and engineered from outside, was rapidly approaching a condition of complete order and great prosperity. He earnestly hoped that, in spite of the handicap of an apparently top-heavy and unduly expensive organization, Assam would continue to flourish in the future as it had done in the past, and he was quite certain that if anyone could ensure the fulfilment of this hope, it was the Governor-elect, his old friend Mr. Laurie Hammond, who had earned such well deserved popularity and esteem among all classes in Bihar and Orissa.

It might be thought that, instead of talking about Assam, as he had been invited to do, the speaker had given his audience little more than a catalogue of names. If so, he pleaded guilty and was unashamed, for India cherished the names of her old and devoted servants—names which were likely to be monuments more enduring than the brass of detraction.

LT.-COL. JOHN SHAKESPEAR, C.M.G., C.I.E., D.S.O., said it was a great honour to be asked to say a few words on the subject, and it was very pleasant for old fellows like himself to be able to turn over the leaves of their memory at such a lecture as he had just heard. The lecturer had said that Assam was not an army recruiting area, but he could remember very stout fellows from Assam in the early days in the old Chittagong Hill Tract forces, and all through the little turn-ups that took place he could not remember one case in which those men did not behave thoroughly well. For the ordinary pioneering work of the frontier the Jheruah was as good a man as the Ghurka. It was to be remembered that when a European was killed in battle his name was handed down with reverence and his people were proud of it, but a Naga who was killed was considered to have disgraced himself, and his name was omitted from the list when his descendants at the great feast recited the names of all their forbears. It was a proud fact that a large number of Nagas, not only from our own territory, but from across the borders were so inspired with confidence in British officers that they came over to France and had the chance of meeting one of those "boxes" the lecturer had spoken about. With regard to Mr. Noel Williamson, who was killed in the hills, he came to him (the speaker) as a young assistant, the first appointment he had ever had, and was a wonderful man in dealing with men and made a great impression on the Lushais, and in fact, on everybody. The lecturer had rather implied that he was to blame for his own death and that of others of the party by overconfidence, but it had to be pointed out that frontier officers must take risks. Mr. Lewin, who had a frontier to guard and was very much bothered with raiders, tells, in "The Fly on the Wheel," how one day he had an invitation to go and see one of the chiefs. He was advised by the natives not to go, but he went, and in the account he gave of the visit he related how by a trick of *legerdemain* he made people think he was impervious to bullets and established such a prestige that he could go anywhere on the frontier and the

chiefs, instead of being a danger, became a safeguard. On another occasion Lewin was engaged in an expedition and, as food was getting short and the weather was bad, it was important to bring the matter to an end. The Lushai was an elusive person. One night in the dark Lewin heard a voice outside his little hut and he was told that the chiefs were waiting for him down by the stream, and Lewin all alone in the dark crossed the stream and the Lushais closed in behind him and he had an interview with the people and settled the whole matter. He took a risk and it turned out to be right. The case of Mr. Noel Williamson was of a similar kind, and he was killed in the performance of his duty. On that occasion there was no doubt that the people did not mean any treachery, but one of the Chuprassis who were sent back, for something thought he would frighten the people by saying that the Sahib was very angry because they had stolen something from his camp and said that he was going to fetch back sipahis. That set the whole country afire and Noel Williamson and his party were killed.

MR. ARTHUR PLAYFAIR, C.I.E. said that although representatives of the tea industry in Assam might sometimes in safeguarding their interests have a grievance against the Government, they had never had a grievance against the Government's representatives in Assam. Relations between planters and officials had always been on the most cordial footing and there was a long list of administrators who had earned the gratitude and esteem of the non-official people.

SIR CHARLES BAYLEY, proposed a vote of thanks to the lecturer for his interesting paper, which he was sure the audience had thoroughly enjoyed.

The motion having been carried unanimously, the meeting terminated.

CORRESPONDENCE

THE SHORTAGE OF AGRICULTURAL LABOUR.

Your issue of the 20th May, 1927, contains a valuable paper by Mr. C. S. Orwin, M.A., on "The Transition of Agriculture," also an instructive discussion.

The speakers all agreed that agriculture in this country was short of labour and that the shortage would increase unless wages were raised. None of the speakers referred to one of the chief causes of this labour shortage, which is as follows :

The Education and other Acts of Parliament make attendance at school compulsory up to the age of 14 and beyond to the end of the school term.

The remedy is to abolish all compulsion, to allow the parents to send their children to school or to work on the land, as gardeners, poultry keepers, bee keepers, to pluck weeds in the fields, to fetch home cattle, and generally to learn something useful, and to earn wages. With these wages they could buy food and so grow up to be strong and clever men and women, and they would become capable farm labourers, small holders, and gardeners. In winter evenings and Sunday schools they would get more book learning than they get now.

Compulsory schooling with the cane or the strap, and without wages, is wicked and cruel, and causes degeneration of the race.

ARNOLD LUPTON.

THE CHINESE DRUG TRADE.

In the course of a recent report on the Chinese drug trade (the term "drug" including any substance used as a medicine) the United States Consul at Chefoo states that although foreign drug manufacturers are well represented in China, the sales of their products are largely confined to the foreign population, hospitals and foreign educated Chinese. The average Chinese does not, as a rule, use alien prepared drugs or medicines, as his confidence in them is not yet established. Foreign doctors, surgeons, hospitals, and medicines are the last extreme and only resorted to when all else has failed. Even a large proportion of the educated class still adheres to the ancient remedies prepared and sold by the native Chinese drug store. This type of store has existed for centuries and caters to the medicinal needs of the masses, rich and poor, educated and uneducated.

There are many crude locally made medicines sold in Chinese drug stores. Some of these medicines are made up according to very ancient prescriptions which are closely guarded by their owners. In olden times the drug business was in the hands of people who were in some degree acquainted with the properties of the drugs which they were selling. At the present time, however, anybody who has money enough to go into this business may do so, as there are no Government restrictions preventing a person from plying this trade.

Among the costly drugs are musk ; ginseng ; very small pearls ; tiger bones ; kidney and galls of bear ; antlers of young deer ; European saffron flowers ; the white flower snake (used for curing leprosy) ; mei-pien (white fluid crystal), said to be frozen vapour of large snakes ; new-hwang (rich yellow powder), said to be gall of very large and fat bulls ; chu-sha (scarlet crystal), said to be a mineral used to pacify patients suffering from palpitation of the heart ; and rhubarb. The bulk of the herbs and drugs comes from Yunnan, Szechwan, Kweichow, Honan, and Shantung Provinces. Limited amounts are also imported from Burma, Siam, Tibet, Ceylon, and elsewhere. Ginseng, best quality, comes from Manchuria and Chosen (Korea) and has been imported in considerable quantities from the United States since the eighteenth century. Hongkong is the centre of this import trade, and in the period 1900 to 1925 the annual receipts exceeded 100,000 pounds. Ginseng also grows in the delta of the Laiyang district, near Chefoo.

Ginseng for centuries has been considered the basic remedy of the Chinese materia medica, and is credited with wonderful restorative and tonic properties. It is prepared for use in several different forms, but it is usually brewed into a tea or chopped into pieces and added to the food. The name is derived from the Chinese word, "jen," meaning men, because of its resemblance to the form of a man—the stem of the root representing the head ; the root itself, the body ; the shoots, the arms ; and the forked ends of the root, the legs. All specimens, however, do not conform with the shape of the figure, but the closer the resemblance the greater the medicinal value attributed to the specimen. The native wild ginseng, as a rule, yields the greatest number of "man-image" roots and consequently brings a higher price than the cultivated variety from Japan and the United States. In addition to the factor of shape, different parts of China lay stress upon the colour and texture. Some localities prefer it in certain colours and spongy and wrinkled or brittle and smooth. The size is also of importance. These and other differences in taste, based on superstition, tend to make grading a rather intricate process. Incidentally, ginseng has little or no therapeutic value in the opinion of Western authorities.

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FRIDAY, JULY 1st, 1927.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. 2.

FINANCIAL STATEMENT FOR 1926.

The following statement is published in this week's *Journal* in accordance with Sec. 40 of the Society's Bye-laws:—

INCOME AND EXPENDITURE ACCOUNT.

January 1st to December 31st, 1926.

Dr.	£	s.	d.	£	s.	d.	Cr.	£	s.	d.	£	s.	d.
To <i>Journal</i> , including Printing, Publishing and Advertisements	3,618	6	9				By Subscriptions	6,308	14	0			
„ Library and Bookbinding ..	137	1	6				„ Life Compositions	575	0	0			
„ Medals:—											6,883	14	0
Albert	22	1	0				„ Interest and Dividends on Society's Investments ..	353	18	1			
Society's	31	4	0				„ Ground Rents	369	5	0			
				53	5	0	„ Interest, Dividends, and Ground Rents from Trust Funds for General Purposes	499	7	10			
„ Cantor Lectures	162	2	6				Do. from Building and Endowment Funds	22	7	5			
						3,970					1,244	18	4
„ Expenses of Examinations ..						12,126							
„ House:—							„ Sales, etc.:—						
Rates and Taxes	377	3	3				<i>Journal</i>	200	2	1			
Insurance, Gas, Coal, Expenses and Charges incidental to Meetings	794	9	0				Do. Advertisements	750	0	0			
Repairs	128	4	6				Cantor Lectures	16	14	3			
						1,290					975	16	4
„ Office Expenses:—							„ Examination Fees and Advertisements in and Sale of Examination Papers	14,127	19	7			
Salaries, Wages, and Pensions	4,138	18	0				„ Charges for Expenses for the use of Meeting Room	311	13	0			
Stationery and Office Printing	523	9	7				„ Rent of Cellars	75	0	0			
Postages, Parcels, and Messengers' Fares	262	10	0										
						4,924							
„ Committees:—													
General Expenses						38							
„ Industrial Art Committees ..						306							
„ Interest on Bank Overdraft ..						122							
„ Balance, being Excess of Income over Expenditure transferred to Capital Account (see Balance Sheet)						828							
						£23,619					£23,619		
						1					1		
						3					3		

TRUST INCOME AND EXPENDITURE ACCOUNTS.

Dr.	£ s d.	Cr.	Trust Accumulations Dec. 31st, 1926.	
			£ s. d.	£ s. d.
Balance forward	988 14 4	By JOHN STOCK TRUST—		
		Balance, January 1st, 1926	42 16 11	
		Interest on Investments	3 10 2	46 7 1
		NORTH LONDON EXHIBITION TRUST—		
		Balance, January 1st, 1926	57 5 4	
		Interest on Investments	6 14 10	64
		DR. ALDRED'S TRUST—		
		Balance, January 1st, 1926	67 12 10	
		Interest on Investments	7 14 5	
			75 7 3	
		Less cost of Prof. Thomson's Lecture	10 0 0	65 7 3
		THOMAS HOWARD'S TRUST—		
		Balance, January 1st, 1926	67 18 4	
		Interest on Investments	19 19 8	87 18 0
		MULREADY TRUST—		
		Balance, January 1st, 1926	44 3 5	
		Interest on Investments	5 5 4	49 8 9
		DR. SWINEY'S TRUST—		
		Balance, January 1st, 1926	80 0 0	
		Ground Rents (Income from) ..	180 0 0	
			260 0 0	
		Less Transfer to Society's Income and Expenditure a/c ..	140 0 0	120 0 0
		FRANCIS COBB TRUST—		
		Balance, January 1st, 1926	36 2 5	
		Interest on Investments	8 18 10	45 1 3
		LE NEVE FOSTER PRIZE TRUST—		
		Balance, January 1st, 1926	12 7 4	
		Interest on Investments	5 16 0	18 3 4
		FOTHERGILL TRUST—		
		Balance, January 1st, 1926	103 9 1	
		Interest on Investments	13 12 5	
		Less paid to J. E. Keay for Prize Essay ..	117 1 6 100 0 0	17 1 6
		BENJAMIN SHAW TRUST—		
		Balance, January 1st, 1926	18 3 8	
		Interest on Investments	4 13 6	22 17 2
		CANTOR TRUST—		
		Interest on Investments	140 5 2	
		Ground Rents (Income from) ..	141 0 0	
			281 5 2	
		Less Transfer to Society's In- come and Expenditure a/c ..	281 5 2	- - -
		DAVIS TRUST—		
		Interest on Investments	78 2 8	
		Less Transfer to Society's In- come & Expenditure Account ..	78 2 8	- - -
		SIR GEORGE BIRDWOOD MEMORIAL TRUST—		
		Interest on Investments	36 15 0	
		Less cost of S. r. M. O'Dawer's Lecture (Including Printing) ..	36 15 0	- - -
		RUSSIAN EMBASSY PRIZE TRUST—		
		Balance, January 1st, 1926	20 0 0	
		Interest on Investments	5 0 0	25 0 0
		DR. MANN TRUST—		
		Balance, January 1st, 1926	98 10 3	
		Interest on Investments	51 8 6	
			149 18 9	
		Less Cost of Juvenile Lectures ..	58 12 2	91 6 7
		Carried forward		652 11 1

TRUST INCOME AND EXPENDITURE ACCOUNTS—*continued*.

Brought forward £ s. d.
988 14 4

		£	s.	d.
Brought forward		652	11	1
OWEN JONES MEMORIAL TRUST—				
To	Interest on Investments	15	13	4
	Less Prizes awarded	15	13	4
THOMAS GRAY TRUST—				
„	Balance, Jan. 1926	113	14	5
„	Interest on Investments	227	8	10
		341	3	3
	Less Prize awarded	5	0	0
		336	3	3
TRUEMAN WOOD LECTURE TRUST—				
„	Balance due to the Society	9	5	4
„	Interest on Investments	32	14	8
		23	0	4
	Less cost of Prof. Tillyard's Lecture	23	9	4
		£988	14	4

£988 14 4

1927—Jan. 1. By Balance brought forward £988 14 4

BALANCE SHEET. December 31st, 1926.

Dr.	£	s.	d.	£	s.	d.
To Capital Account—						
As on January 1st, 1926	74,987	13	5			
Donations <i>re</i> Building Fund ..	451	3	0			
Income and Expenditure Account Balance ..	828	15	9			
			76,267	12	2	
„ Sundry Creditors ..			956	0	4	
„ Bank Overdraft ..			3,653	14	2	
„ Industrial Art Fund (Donations received and not yet expended) ..			128	11	0	
„ Preservation of Ancient Cottages Fund (Donations received and not yet expended) ..			776	5	0	
„ Donation received and not yet expended for re-fronting the Strand front of the Society's premises ..			1,000	0	0	
			82,782	2	9	
„ Trust Funds —						
Capital Account ..	21,899	7	5			
Accumulations under Trust Income and Expenditure Account ..	988	14	4			
			22,888	1	9	
			£105,670	4	6	

Cr.	£	s.	d.	£	s.	d.
By Freehold Premises						
18 and 19 John Street, as on December 31st, 1923 ..	50,392	16	7			
„ Books, Pictures etc. ..	10,000	0	0			
„ Investments (see schedule) ..	17,481	8	5			
„ Subscriptions out standing ..	2,608	2	0			
„ Sundry Debtors and Ground Rents outstanding ..	998	10	1			
„ Paid on Account of 1927 Examinations ..	2,200	0	0			
	82,680	17	1			
„ Trust Funds—						
Investments ..	21,899	7	5			
Ground Rents, etc. ..	90	0	0			
	21,989	7	5			
			£105,670	4	6	

We have audited the above Accounts and Balance Sheet for 1926 with the books, accounts and vouchers relating thereto, and certify them as being in accordance therewith. We have verified the Bank Balances and investments.

KNOX, CROPPER & Co.,

Chartered Accountants

Spencer House, South Place, E.C. 2.

15th June, 1927.

SCHEDULE OF THE SOCIETY'S INVESTMENTS.

(as valued December, 1922).

Ground-rents (amount invested)	£10,496	2	9
£217 0 0 Great Indian Peninsula Railway 4 per Cent. Guaranteed Debenture Stock	157	0	0
£500 0 0 New South Wales 4 per Cent. Stock	445	0	0
£500 0 0 Canada 3½ per Cent. Stock	430	0	0
£100 0 0 Queensland 4 per Cent. Stock	97	0	0
£530 10 1 New South Wales 5 per Cent. Stock	514	11	0
£500 0 0 Natal 4 per Cent. Stock	445	0	0
£321 15 9 Metropolitan Water Board "B" Stock	209	3	0
£8 0 0 New River Company Shares	6	0	0
£3,408 14 6 India 3½ per Cent. Stock	2,181	11	8
£500 0 0 South Australia 4 per Cent. Stock	500	0	0
£2,000 0 0 War Loan 5 per Cent.	2,000	0	0
	£17,481	8	5

TRUST FUNDS INVESTMENTS SCHEDULE.

Alfred Davies Bequest	£1,953	0	0	Great Indian Peninsula Railway 4 per Cent. Guaranteed Debenture Stock ..	£1,800	0	0
Dr. Swiney's Bequest	4,477	10	0	Ground-rents (amount expended).....	4,477	10	0
Dr. Cantor's Bequest	2,695	11	3	Do. do.	2,695	11	3
Mulready Trust	105	9	9	National 5 per cent. War Bond, 1927 ..	109	10	1
Howard Trust	571	0	0	Metropolitan Railway 3½ per Cent. Stock	510	9	5
Owen Jones Trust	522	3	2	India 3 per cent. Stock	423	0	0
Dr. Cantor's Bequest	3,273	16	6	Do. do.			
	648	19	7	Bombay & Baroda Railway Guaranteed 3 per Cent. Stock	2,573	10	0
J. Murray and others, Building Fund ..	20	16	4	India 3½ per Cent. Stock	20	10	0
	38	11	0	5 per Cent. War Loan	54	18	0
Francis Cobb Trust	255	14	1	New South Wales 3½ per Cent. Stock 1930-50	250	0	0
Le Neve Foster Trust	105	11	7	3½ per Cent. War Loan	100	0	0
	42	2	1	5 do. do.	40	0	0
John Stock Trust	70	4	0	5 do. do.	100	0	0
Shaw Trust	93	12	0	5 do. do.	129	6	8
North London Exhibition Trust	134	17	0	5 do. do.	184	15	0
Fothergill Trust	272	7	6	5 do. do.	374	0	0
Aldred Trust	154	8	0	5 do. do.	210	17	6
Endowment Fund	394	7	0	5 do. do.	525	2	3
"Trueman Wood" Lecture Endowment Fund	654	15	7	National 5 per Cent. War Bonds, 1928 ..	654	18	0
Sir George Birdwood Memorial Fund ..	734	19	9	5 per Cent. War Loan	674	0	0
Russian Embassy Prize	100	0	0	5 do. do.	91	9	3
Mann Trust	1,023	9	2	5 do. do.	900	0	0
Thomas Gray Memorial Trust	6,498	7	9	3½ do. do. Conversion Loan	5000	0	0

£21,899 7 5

NOTICE.

POSTPONEMENT OF ANNUAL GENERAL MEETING.

Owing to the eclipse of the sun on June 29th, the One-hundred-and-seventy-third Annual General Meeting, for the purpose of receiving the Council's Report and the Financial Statement for 1926, for the revision of the Bye-laws, and also for the election of Officers and new Fellows, has been postponed, by order of the Chairman of the Council, to Wednesday, July 6th, at 4 p.m.

GEORGE KENNETH MENZIES,

Secretary.

PROCEEDINGS OF THE SOCIETY.

DOMINIONS AND COLONIES SECTION.

TUESDAY, MAY 31ST, 1927.

SIR CHARLES S. BAYLEY, G.C.I.E., K.C.S.I., a Vice-President of the Council, in the Chair.

THE CHAIRMAN said that it had been a very great disappointment to him, and no doubt, to all present that Lord Selborne, who had promised to take the Chair, was unable to do so, having been called away by urgent business in the House of Lords. The Chairman of the Council, Sir Thomas Holland, would have taken his place, but was unfortunately engaged, and, as he (the Speaker) was the only member of the Council available, the duty and pleasure of taking the chair had devolved on him. He could not help wishing that this had not been the case, for he was ashamed to say that he had never visited either Morocco or Spain. The subject, however, of Dr. Baldasano's paper, which it had been his privilege to read, was one of great interest to him, for the problem confronting the Spaniards in Morocco, that of the relations between a dominant European and an Oriental race, was similar in many respects to that confronting the English in India with which he had himself been connected for the greater part of his life.

The following paper was then read :—

SPANISH MOROCCO.

By SEÑOR DON TOMAS BALDASANO, LL.D.,

Caballero de Isabel la Catolica, London Correspondent of La Epoca, Madrid.

I think it would be well to give a few preliminary facts on the physical and the historical features of Morocco, in order better to define the position of Spain in North Africa.

I will note in the first place that the geographical situation of the Moroccan Empire and the conditions of the territory, have influenced its historic destinies

in an extraordinary degree. Situated in the North-west extremity of the African continent, it was at all times the road followed in the migrations of ancient peoples and the succession of conquerors was determined by the peculiar topography of the country. Its hydrographical conditions are more favourable than those of other northern African territories, excepting the Nile region, a great number of rivers having their origin in the mountain ranges. It is interesting to note here that in Morocco the great Atlas and the lesser Atlas, this latter known as the "Mountains of the Rif," rising from the Mediterranean, to which they run parallel, constitute the peculiar characteristic of the country, forming an impenetrable barrier that has prevented the Moroccan Empire from forming in history a nationality after the manner of European countries. The races sharing the possession of the Moroccan territory are the Berber and Arab, and although living under similar conditions maintain their ethnical character almost pure, the Berbers inspired by a spirit of rebellion, and the Arabs by ancestral pride. Such conditions have brought about the result that, although in the pathway of civilisation, the Moroccan peoples have remained refractory to European influences.

Spain is attracted to Morocco by considerations of a multiple character. She is attracted by connections with the Moorish race extending over many centuries, and the two races have been in turn fighting, at peace, or negotiating agreements. The historical links of Spain to Morocco are well known. In the Roman age North Africa, or Mauretania Tingitana, was under the Betic Government, and was called Hispania Tingitana, Seville being the capital of the province.

Setting aside military facts, it is curious to note the traces left in Spain by the Moors. Many Moroccan families descended from Spanish Moors have Spanish names, and still preserve as sacred relics the title and the keys of the palaces left in our land. These are the bonds which the course of centuries has not destroyed. Architecture and fine arts attained among the Moors in Spain the splendour of eastern magnificence. The monuments, such as the Mosque of Cordoba, the Alcazar of Seville, and the Alhambra of Granada, are all works of the Moorish genius.

The decay of Morocco brought about a lamentable state of confusion and anarchy in the political and social organisation of the country. Supreme power is antagonistic to the independent character of the people, who, grouped in different tribes, almost ignore any principle of authority.

In the early part of this century the state of Morocco led the European powers, as we all know, to intervene. The Algeciras Conference of 1912 consecrated the intervention of Spain in Morocco. Prior to this treaty, other important agreements were signed relating to the influence to be exercised in the Sheriffian Empire—the Franco-British Treaty, and the Franco-Spanish Secret Treaty. Perhaps the most important was that signed in 1904 in consequence of the Madrid Conference of 1893. This document conferred upon

the contracting nations the "most favoured nation Clause," and established the rules relating to diplomatic and commercial protection.

Morocco, by virtue of the Algeciras Treaty, was divided into three zones. A very extensive zone is subject to French influence, another zone of minor extent is under the Spanish protectorate, and a third zone formed by Tangier and its district, though within the Spanish zone, is under an international regime.

The Spanish zone of about twenty-five thousand square kilometres is almost included in the Rif on the Mediterranean coast of North Africa. Its northern limits are the Strait of Gibraltar and the Mediterranean, its coast extending for three hundred kilometres from the Almina point to the Muluya River, which marks the Algerian Frontier. Its eastern limit is Algiers; on the south it is bounded by the French zone, and on the west by the Atlantic Ocean.

The Spanish Protectorate is administered by a High Commissioner, the supreme military and civil authority. A Department for Moroccan affairs at the Madrid Foreign Office assists the Head of the Government in dealing with Moroccan problems submitted by the Protectorate Authorities. The High Commissioner controls the various administrative departments, which include a General Secretariat, and the departments of public works, agriculture, mining, municipal services, finance, customs, postal services, and the Courts of Justice. The native organisation, under the Khalifa, consists of the following departments: the Khalifa's household, the Grand Vizir, the Administration of Islamic Justice, the Ministers of Finance and Education and the Baja of Tetuan.

The history of Morocco shows how much more difficult the North of the country has been to govern than the South; due to the fact that the greater part of the territory assigned to Spain is known as "Bled Siba," or "the unsubdued country,"—the absolutely independent country of the Jibala and the Rif, never conquered by the Sultans and possessing a semi-feudal and primitive form of government adverse to any sort of peace or civilization.

Spain, from the time of the signature of the Algeciras Treaty, has resolutely directed her policy towards gaining the goodwill of the natives by peaceful means and by developing the natural resources of her zone.

It is not possible, within the limits of a single lecture, to give a detailed account of the work of Spain in Morocco in carrying out her policy of establishing conditions of peace and prosperity. I propose to dwell upon a single aspect—that of the development of the natural resources of the country for the creation of wealth in harmony with its possibilities and the psychology of its people.

In attempting to describe this policy of Spain, developed parallel to the state of war which ended with the surrender of the Rif leader Abd-el-Krim—although military operations are still in progress for the purpose of obtaining the total occupation and submission of the zone—I will refer to the work carried out for the improvement of the towns, and of railway and road communication, the

establishment of mining enterprises, the development of agriculture and colonisation, education, and the institution of benevolent societies. In my concluding remarks I will describe the general commercial and financial position.

The initial effort towards the realisation of the economic policy consisted in the establishment of Spanish mining enterprises in the Jibala district by the *Compañía Española de Minas del Rif*, which since 1907 has been engaged in the development of the Uicsan iron mine in the eastern Rif. The history of the Company is closely connected with the military events of 1909 in the Jibala. A Spanish group, after negotiations with the once famous agitator, Muley Muhammad, better known as El Roghi and Bu Amara, who dominated the Rif district, took possession of the mine in 1908 by virtue of an agreement with El Roghi, who exercised at the time an effective authority in the district. The rebellion of the Jibala tribes in 1908 against Muley Muhammad interrupted the progress of the work, but when peace was restored, operations were actively resumed and the construction of the San Juan de las Minas Railway was completed.

This Mining Company, together with another mining enterprise, the Setolazar, founded in 1913 by a Bilbao group and exploiting the Navarrete Iron Concession adjoining the concession of the *Compañía Española de Minas del Rif*, develops simultaneously with the Government the peaceful penetration of these uncivilised districts.

The two Companies, since resuming operations, have given employment to thousands of natives. Spaniards and Moors live in harmony whilst building railways, roads, and other communications; and this opportunity of remunerative work at the same time changes the former miserable condition of the tribesmen into one of prosperity. European settlements, consisting of as many as sixty-four houses, a co-operative store for the staff, a school for native and Spanish children, have been established by these Companies. The action of the Miners of Uicsan determined the construction of a Catholic Church, in addition to Infirmaries, Dispensaries, and Souks. These have also proved to be an attraction to the tribes of the interior.

After the submission of the rebels, the Spanish Minister of Public Works visited the zone accompanied by a body of engineers, doctors, teachers, and linguists to carry out plans for public works and to establish schools and charitable institutions. This policy was initiated in pre-Protectorate days, when Spain had not yet contracted the international obligation imposed by the Treaty of Algeciras. The inactive periods in the execution of this programme are to be ascribed to the hostility of the tribes.

Melilla and Ceuta on the northern coast are the two chief towns in the centre of the zone. For this reason Spain made them the two bases for her action. They have developed considerably. In 1900 the population of Melilla numbered four thousand inhabitants; in 1925 the actual population had risen to

upwards of fifty two thousand. Tetuan, the capital of the Protectorate, known as the "White Town," has been greatly improved under the direction of a special section of the department of Public Works, created for the construction, improvement and maintenance of buildings. It restored to its magnificence the Palace of the High Commissioner and of the Khalifa.

In 1916 the so-called policy of the conciliation of the native was initiated by the establishment of Dispensaries, and the construction of important buildings, such as those for the Spanish-Arabian School of Tetuan, the Rio Martin and the Alcazarquivir Schools, while an old fondak was adapted as a School for Arts and Crafts. The policy of protecting the native against misery made us many friends. It is interesting to give in this connection a few illustrations on the screen of the results of this policy.

The town of Melilla devotes annually over two hundred thousand pesetas to charitable purposes. It is within the mark to say that half of this amount serves to relieve the necessities of the natives. The hospitals of Melilla, particularly the one presented by the town to the Red Cross, are of the latest type. Spaniards, Moors, and Hebrews are assisted in these Institutions. The Spanish Authorities do not confine themselves to the town, for they extend their action beyond it. In fact, medical services are in such demand that as soon as hospitals are opened they are freely visited. Here, in this human mission, lies one of the most powerful instruments of Spain for bringing about a peaceful union with the natives. The old Tetuan Dispensary under municipal control dealt, in 1925, with thirty-three thousand cases, of which nine thousand were natives, five thousand Hebrews, the remainder Spaniards and foreigners. These services are absolutely free to the natives. The Dispensaries of Arcila and Laraiche have also done very valuable service.

The towns of Arcila and Laraiche are on the Atlantic coast. The port of Arcila, though overshadowed by Laraiche and Tangier, will be greatly developed on the completion of the docks extension scheme which is now being carried out, and it will become an important centre for supplying large areas dependent to-day on Tangier.

Laraiche, at the mouth of the Luccus River, enjoys an exceptionally favourable position and is bound to become the centre for the reception and distribution of goods to the interior. The harbour possesses a dock six hundred metres long, and a wharf two hundred and twenty-five metres long, with a draught of two metres. To maintain the depth dredging operations are carried out by the "Morocco Dredger." The "Morocco" is fitted with pipes at the bow and along the sides, through which the material dredged is carried to large buckets of four hundred cubic metres capacity, and then through iron tubes to the marshes of the Luccus, near Laraiche, and deposited there to raise the level of this low-lying land. By this process about four hundred thousand square metres of land have been recovered and fertilized.

Chechouan, since its occupation, has been treated with particular solicitude. Anything which might offend the susceptibilities of this ancient city has been carefully avoided. European quarters were established outside the town when the campaign of Alhucemas, planned and successfully carried out under the command of General Primo de Rivera, compelled its abandonment.

The peaceful penetration of the zone has been accompanied by the development of what were formerly miserable Moorish villages into true urban districts, such as Rador, Zeluan, Monte-Arruit, St. Juan de las Minas, Cabo de Agua, and Restinga in the eastern sector, Rio Martin, Malalian, Rincon del Medick and others in the western zone.

In spite of former antagonisms, friction is rarely reported, natives and Spaniards living in mutual tolerance. The Moors are aware that their beliefs and customs are respected, and that the practice of their religion is not interfered with. They also know that they are paid good prices for anything bought from them.

The efforts in Spanish Morocco to improve the towns were accompanied by the establishment of communications between the different parts of the zone. The railways, excepting the mining railway of Melilla, are the property of the Makhzen, who is responsible for the working expenses of certain lines, such as the Nador-Tistutin and the Laraiche-Alcarzarquivir. In the case of the Ceuta-Tetuan Railway, the Makhzen granted a lease in exchange for a share of the revenue.

Not many years ago communications in Morocco were unknown. The construction of roads, bridges, railways and other public works inspired horror among the natives. It was only under the influence of the European powers that various ports were opened along the coast for trade. A horse or a camel were sufficient, and even now are sufficient, for the native to cover any distance. But the Spanish authorities undertook the construction of railways in the belief that they would exercise upon the Moor a civilising influence.

Apart from the railways and roads built for military purposes, the Spanish zone is provided with a fair number of railway and road communications for the requirements of the various districts. Greater results would have been reached had it not been for the continual opposition of certain rebel tribes. Apart from the military railway from Melilla to San Juan de las Minas in the eastern section the Melilla Railway extending over thirty-six kilometres, as far as Tistutin, was built by the Department of Public Works. Starting at Nador, where the railway works are situated, it links with the Melilla-Segangan Line of the C.E.M. del Rif.

The working of this small line shows some interesting figures. It transported in 1925 over 192,000 passengers and 63,278,000 kilograms of goods. The gross revenue of the line was 669,709 pesetas and the net receipts were 204,636 pesetas.

The Ceuta-Tetuan railway connecting the capital of the Protectorate with the important port of Tetuan is about forty-five kilometres in length and has eight Moorish-built stations. It travels through several tunnels and passes over six bridges, built by Spanish and native labour. In 1925 it transported over 495,000 passengers, and about 50,000,000 kilograms of goods. A narrow-gauge military railway connects Rio Martin, Tetuan, Lucien, and Ben Karrik.

The Laraiche-Alcazar Railway is forty kilometres in length. It serves the traffic between the two southern towns of the western section. It is a remarkable work of engineering, particularly the bridge over the Luccus. It runs five daily passenger trains and maintains a regular and punctual service. The Port Station receives from the ships goods for the inland markets. The Laraiche-Mensah Station, near which are situated the railway works, has a large passenger traffic. The Anamara Station lies near the military Aerodrome and Stud establishment. Alcazar is the Junction Station with the Tangier-Fez Railway. In the last six months of 1926, the income totalled 299,000 pesetas, of which about 138,000 pesetas were derived from passenger and 161,000 pesetas from goods traffic.

I should note here how the competition of motor traffic has hindered the further development of the Laraiche-Alcazar Railway. An interesting feature of this line is the fact that a large part of the traffic flows from the coast to the interior.

The Spanish section of the Tangier-Fez Railway extends over ninety-two kilometres of our zone and possesses three tunnels, one of 140 metres in length, another of 130 metres, and a third of 135 metres. It is also provided with bridges for the passage of rivers. Arcila and Alcarquivir are the two main Stations under construction. The international gauge question of the Ceuta-Tetuan Railway is under consideration by the Public Works Department in view of the Government's decision to build a Railway from Ceuta to Alcazarquivir, crossing the Jibala from north to south. The high importance of this line from the commercial and colonising stand-point make it probable that it will be constructed and opened for traffic in the immediate future, the Spanish Government being determined to carry out the pacification and the economic exploitation of the Jibala district.

I have dealt at some length on the railways of Spanish Morocco, for it is a well-established fact that good communications are essential to the establishment of peace, specially in this part of Northern Africa.

In the matter of roads the Public Works Department have carried out a perhaps too elaborate programme, as the upkeep of the roads is rendered difficult by the nature of the soil. The civil roads, designed purely for commercial and agricultural purposes, and constructed partly by private companies, are under the control of the Public Works Department.

The principal roads are : The Mellilla-Nador and Zeluan, twenty-seven kilometres long, with a daily motor traffic of eight hundred vehicles. From Zeluan

this road leads to Zais, crossing the Zeluan River, and extends for over ten kilometres as far as the Muluya River. It is twenty-six kilometres in length, and is bound to have a great importance when the international bridge, connecting Melilla to Uxda, is constructed.

The Nador to San Juan de las Minas, nine kilometres long, to Segagan and San Juan.

The Zaio to Cabo del Agua road, under construction. This road will extend fifty-eight kilometres through very rich lands and will become an important outlet for the agricultural products of the Quebedana region, which is a subdued and pacified district.

The circular road of Tetuan connecting the Ceuta-Tetuan road to the Tetuan-Tangier road, and the Tetuan to the Rio Martin.

This road was constructed under extreme difficulty in certain sections, owing to the heavy labour entailed in making the unstable soil firm and solid. It also involved the construction of six concrete bridges across various rivers.

The Tetuan-Tangier road, which is one of the roughest main highways in Morocco, is still under construction.

The Tangier-Rabat road, one hundred kilometres of which are in the Spanish zone. The Luccus River is crossed near Alcazar by a suspension bridge erected and maintained by the War Department. The difficulty of maintaining this road in good condition owing to the torrential rains, the dry soil, and heavy winds, has made the use of asphalt necessary. In 1926 the work of making an asphalt surface was begun.

The Laraiche-Alcazar Railway and the Tangier-Fez Railway are utilised to transport material from the Ufrur Quarry between Tangier and Fez. The roads are repaired by contract and steam-rollers are employed upon them by the Public Works Department. In 1926 over fifty kilometres were repaired at a cost of eight hundred and ninety thousand pesetas.

The Public Works carried out by the military administration include a number of roads and railways of a total length of nearly nine hundred kilometres.

The Government have further decided to extend existing communications by investing over fifty million pesetas in the construction of roads and the improvement of various municipal services.

Another important aspect of the economic policy in Spanish Morocco is agriculture. This most essential factor of the wealth of the people is, in the Spanish zone, in a primitive state. Morocco is a country endowed so richly by nature that it could produce not merely sufficient to satisfy the necessities of its inhabitants, but an abundant surplus to meet the needs of less fertile countries. But the Moroccan is indolent, and confines his efforts to cultivating the land adjoining his dwelling for a bare maintenance for himself and his family; a task not demanding great effort owing to the fertility of the soil and a frugal manner of life. He cultivates his scanty acres with the same imple-

ments as were used in remote antiquity. A prominent authority on African affairs, who travelled throughout the territory and devoted his investigations to Northern Morocco, wrote that "the soil is of such an inexhaustible wealth, that by itself it could provide the whole of Europe with wheat, oats, and other cereals."

Production, however, is being largely stimulated by establishing settlements of Spanish agriculturalists. The agricultural service of Spanish Morocco is an organization worthy of high praise, and practises the most modern principles of scientific agriculture. The first work carried out was the installation of an experimental farm in Laraiche, the agricultural centre of the Protectorate. The farm consists of two different areas and is of great service both to the native Moroccans and to the Spanish settlers. The native is not a wealthy landowner, as is the case in the French zone, but a small proprietor, while the Spanish settler also frequently lacks sufficient means for the proper exploitation of his land. Thus the work of the experimental farm, undertaken alike in the interests of the Spanish settler and the native, contributes to the cause of peace.

The farm includes different sections dealing with the various types of crops with which experiments are carried out. It places at the disposal of the native and settler seed and other requisites for successful production, and protects him to a large extent from the risk of loss.

The spirit of the agricultural services is thus directed to a two-fold object : to guide and assist the settler and to extend its action to the subdued districts. It is hoped that in this way the native may realise the advantages of living in good relationship with the Spanish settler, and that his industry may be stimulated by the fruits of well-directed labour. Such a policy may be expected to eradicate in some degree the native ancestral love for war.

In the experimental farms of Laraiche and Melilla experiments are carried out with the different crops adapted to the agricultural conditions of the soil, such as cereals, European and American grapes, olives, oranges, mulberries, and forage plants. Successful experiments have also been made with cotton and the castor-oil plant.

The nurseries of the Laraiche and Melilla farms provide the settler with fruit trees in a certain abundance, and, though they have not reached their maximum production, supplied in the year 1925 over 50,000 trees of three or four years old, of such varieties as orange, lemon, pear, caquis, plum, cherry, olive, apple, mulberry,

The Laraiche and Melilla farms also give practical instruction in sowing and harvesting for the benefit of the native farmer of the subdued districts. In 1924, a year of medium crops, as a result of such activities, over 76,000 kilograms of wheat and 91,000 kilograms of hay were obtained from four villages. A recent decree has instituted a course of instruction on the experimental farms for the native farmers and a superior agricultural course for the

Spanish settler. Cattle-breeding centres are also to be established on the Laraiche and Melilla farms.

Agricultural colonization has attained interesting results by means of private enterprise. A Spanish concern has carried out the agricultural development of an estate of some thousands of acres. Colonizing operations have also been undertaken by the agricultural school farm of Nador and in the Tetuan, Cueta and Melilla districts, native labour being employed. In many cases the Moorish proprietor of the land is associated with the Spanish settler, and it is an established fact that in agricultural cultivation natives and Spaniards understand each other perfectly. The Moor is the first to recognize the advantages of co-operation with the Spaniard. The infrequency of sales of land in the Protectorate, particularly in the Tetuan and Laraiche districts, is due to this type of agricultural association.

Another feature of the Spanish-Moroccan Administration is the afforestation problem. According to official information a recent survey of the zone by the Department of Public Works, which was made as complete as the existing situation permitted, showed that over 60 per cent. of the area is more or less afforested.

The Department undertook the afforestation of part of the country south of Laraiche, between that town and the French zone, the tree selected being the pine. In the Eastern District the Tizza or Zumaque is greatly in demand for the dyeing and tanning industries. Nurseries of the afforestation service have been installed in Laraiche and Rio Martin, over 297,000 plantings having been registered from 1917 to 1925. In 1917 a certain number of eucalyptus trees, which are sufficiently hardy to withstand the hurricane winds, were planted, and since have grown to a height of 9 metres. Other cultivated species, suffering more or less from the levantes, are the lentisc, palm, pine, white acacia and black poplar tree.

By means of this work of afforestation the agricultural service has increased the resources of the country, while rendering malarious districts more healthy.

The nurseries contain as many as 500,000 pines, 100,000 eucalyptus, 60,000 cypress, and 150,000 mimosas of various species.

I will now consider the work carried out by Spain in respect of organising elementary education as a means of eliminating the profound ignorance which is the principal cause of the uncivilised state of the Rif and Jibala tribes.

The majority of the native population lack even the most rudimentary education. In some of the Jibala tribes students—tolba—are more numerous, and there is therefore a smaller proportion of illiterates.

The schools established in the zone are organized on the plan of the Peninsula elementary institutions. Melilla assigns 250,000 pesetas for education and possesses 35 modern schools. A similar policy in proportion to its population was followed by Ceuta. The general technical school of Melilla is attended by native and Jewish students, and other educational institutions in the town are

the School of the Alliance Israelite Universelle, a School for Arts and Crafts and a number of private establishments. The curriculum conforms with modern standards, and the teaching staff, who are Spanish, number 56 teachers of both sexes. The Spanish Schools are in Tetuan, Laraiche, Alcazarquivir, Arcila, Rincon del Medik, Rio Martin, Nador, Zeluan, Monte Arruit, Segangan and Cabo de Agua. The Spanish Arabian School of Tetuan has three classes: Koranic, Arabic and Spanish, the first two directed by native teachers, the latter in charge of a Spanish instructor. Evening schools for adults attended by natives and Jews have been instituted and circulating libraries have been started in certain rural districts. A scholarship scheme affords opportunities to native students to follow special courses in Madrid. The Budget of the Protectorate assigns for education over 530,000 pesetas annually.

Turning to the commercial side, it is interesting to note how commercial institutions are developed, even by almost uncivilized peoples. Although the natives of the Spanish zone do not require an elaborate commercial organization their small transactions are active and regular. In all tribes, generally speaking, there are market places, called Souks, situated in the town, many of which are well constructed buildings. The best consist of a large square surrounded by walls, the interior arcades being fitted with stalls for the principal merchants. There are also places specially set aside in these souks for the sale of cattle and horses. The principal Souks are those of Laraiche and Tafersit in the Rif and that of El-Hauz-Tittauen in the Jibala.

Commerce in the Spanish zone is almost exclusively in the hands of the Jewish population, the Spanish coming next in importance. The chief commercial centres are Laraiche, Melilla, Ceuta, Rio Martin and Arcila.

The import trade has rapidly increased in the last ten years. The purchasing power of the native has never been very great, though the Moor has sufficient money to supply his needs. In 1922 the imports from various countries amounted to over 188,000,000 kilograms.

The principal Spanish imports into the zone are:—Sugar, rice, beans, fruits, coal, cement, and wheat flour. Mineral ore, hides and fish are the principal exports.

Melilla absorbs almost the whole commercial traffic of the eastern region, owing principally to the activity of mining development. The imports, exports and coastal trade amounted in 1904 to 8,000,000 kilogrammes. This trade had increased in 1924 to 597,000,000 kilogrammes. The export of iron in the same year exceeded 390,000,000 kilogrammes. The port of Melilla is well equipped for the exigencies of this traffic.

The development of Ceuta is similar to that of Melilla, though on a smaller scale. Its harbour will become in the future one of the most important Mediterranean Ports, and will probably surpass Tangier. The Port of Ceuta is well supplied with fuel oil and pumps by which ships can be loaded at a rate of 300 tons an hour. The tanks have a capacity of 24,000 tons of oil. The stock

of coal is abundant to meet all requirements, and there will shortly be storage room at the dockside for 70,000 tons. Thanks to this equipment, the harbour of Ceuta was enabled to meet the necessities of the last campaign, during which it sheltered the Spanish and French Fleets in addition to mercantile and coasting vessels and a number of 16,000 ton liners. In 1925 Ceuta was visited by 2,600 ships, and over 179,000 tons of merchandise were discharged.

Although, as I have pointed out, commercial traffic is rapidly increasing, an active movement is carried out by the Spanish Moroccan Department of Commerce for its further expansion, and a permanent exhibition of Spanish products was opened in Melilla in 1916.

Examining the financial organization of the Spanish zone, we find a taxation system established by ancient Imperial Edicts constituted by a number of tributes of ancient origin, nominal taxes rather than real. The Zekhat and the Archour, of Koranic origin, on capital and crops, and others, such as the Hedia, consisting of a present made by the tribes to the Sultan on the occasion of religious festivities, are still in force, for innovations in these traditional institutions offer serious difficulties.

These tributes were practically suppressed by the Sultan after the Algeciras Treaty. The collection of Customs was modified by the institution of the Debt Control to guarantee the security holders of the 1904 loan.

The Tertib is a direct tax on land and live stock. The Spanish authorities do not always collect this tribute, as in some cases it would involve an inequality of treatment. It is, however, intended to impose this tax upon the tribes after their submission, for this act implies the recognition of the sovereignty entailing the payment of the tax. There is also a tax imposed on mining concessions.

The Act of Algeciras established a 10 per cent. ad valorem duty on imports which is collected by the Native Authorities controlled by Spanish officials. Silk, wines and other articles pay a 5 per cent. ad valorem duty. At the ports of Melilla and Ceuta imports are subject to a 5 per cent. duty by virtue of the Algeciras Treaty establishing a special treatment in respect of these two ports.

Exports are subject to a special ad valorem duty though there are cases of exemption to stimulate the development of the small number of industries established in the zone.

A typical tax is the Souk or market tax, which is organised and controlled by the Spanish Authorities. It has an old history and is collected by the Kaid of the district where the Souk takes place. Following the old custom a portion of the revenue derived from this tax is used to improve the district concerned, another portion covering the expenses for the organisation of the Souk.

By virtue of other Imperial Dahirs special taxes on alcohol and sugar were instituted and are still in force.

The different taxes that I have enumerated and the monopoly on certain products, such as tobacco and sulphur, established by the Act of Algeciras,

together with the taxes derived from rural and urban property and from fisheries, constitute the revenue system in Spanish Morocco.

The Budget system for centuries depended on the extensive right of the Sultan to impose taxation according to his own mentality and financial needs. After the institution of the Spanish and French Protectorate, this regime was suppressed and the Budget was regulated on other principles. The first Budget, drafted in 1917 by the Spanish Government, fixed a subsidy of 7,000,000 pesetas for the Sultan. From 4,112,000 hassanis pesetas in 1913 the taxes collected in the Spanish zone raised the total revenue to 14,324,000 Spanish pesetas. That is to say, owing to the economic policy of the Spanish Protectorate the revenue of the Sultan was seven times higher than that obtained prior to the establishment of the Spanish Protectorate. As a result, the subsidy from the Spanish State was no longer required. In certain years it amounted to 8½ million Spanish pesetas.

As the subsidy granted to cover the deficit of the Budget of the zone has been only partially used, there is an available surplus of 15,000,000 pesetas. The Government has decided to add this capital to the 54,000,000 pesetas to be expended on public works and similar services.

Spain may have made mistakes in her efforts towards the realisation of her mission in North Africa, but it is unquestionable that she never failed to honour her international obligations.

I trust that the facts that I have placed before you, illustrating the material development of the Spanish zone, principally since the rectification of previous policies by the present Government, have in some way contributed to show that the Spanish Moroccan problem is to-day virtually solved.

DISCUSSION.

MR. HENRY LEACH said the only thing he could add in supplementing the very interesting lecture related to some recent experiences of his in the Riff, of which most people in these days had heard, especially last year, when Abd-el-Krim made a good deal of trouble. Few people had any idea of what the Riff was or where it was situated, and had still less knowledge of what the Spaniards were doing there at the present time. He had listened with the greatest interest to what the lecturer had to say about the two instruments of emigration and colonisation that Spain was using, namely, communications and education, both of which were powerful in connection with the matter. A picture had been shown of the new schools at Laraiche, and he knew a great deal about that place because he was there for the first time a good many years before the Spaniards occupied the place. The present Spanish occupation dated from about 1912, and he was there in 1902. It was then more or less a desert, and the natives were living a barbaric life, and there was practically no trade. To-day Laraiche was one of the finest and most modern cities in Northern Africa, splendidly equipped, a place in which it was easy and pleasant to live. When he was there three years ago the new Spanish school was just completed, and a finer school he had not seen anywhere either in Africa or Europe. The curriculum was modern, thorough and comprehensive, and amongst other things

the English language was being taught. In its equipment, class rooms, lecture rooms, and especially on its physical and hygienic side, it was quite perfect. There was a similar but rather smaller school also at Tetuan. With regard to the Riff, he had known Spanish Morocco intimately off and on for about 25 years, having spent long periods there visiting every part, but until a few months ago he had not been through the Riff, nor had anyone in England. By the courtesy and assistance of the Spanish Ambassador and the Government and military authorities in Madrid, especially General Jordana, the Director of Colonies, he was given every facility for going through the Riff, being the first foreigner to do so. He should like to give briefly a few facts which would give some slight idea of what the Spaniards were doing in the matter of colonisation in North Africa at the present time, facts which possibly would change the impression of a great many people who only took their knowledge from reports which were not always unprejudiced. The Riff had been a country perhaps less known than any part of Europe or Africa—and, he believed, Asia. Until recently it was quite unknown. It was a country extending along the Mediterranean for about 120 miles, and at most 50 miles deep, inhabited by various tribes about which little was known. It was a Spanish zone, but the Spaniards had not entered it themselves. The thing that it was not like might be gathered from a musical comedy being played in London at the present time, where, he believed, the Riff was presented as a beautiful country of a golden yellow colour, with palms and Riffian chiefs in purple robes. It was not like that. The Riff was a wild, bare, harsh, ugly country, with nothing inviting about it, and anyone who thought that in the course of a few years they would enjoy touring through the Riff country would find that the Riff would have to change very much. The only beautiful or picturesque part of the country, save for the savage beauty of the wild, was the region inhabited by a tribe called the Ketamas, and it was against that tribe that the Spanish and French forces had been operating recently. He was with the Spanish forces at the base for two days watching the beginning of the operations against the Ketamas. The tribe occupied a valley at a height of about 4,000 feet, and the Spanish were operating from Targuist while the French were on the other side, and the two armies were in conjunction. It would be an outside estimate to say that there were 10,000 Ketamas. There were about 5,000 highly trained soldiers of the Spanish army well equipped with every modern war appliance and probably more of French. He did not think that with 12,000 European soldiers, against perhaps 7,000 to 8,000 Ketamas, the Ketamas had much chance; they were sandwiched between the two armies. After being at the base at Targuist with the Spanish forces, he was able at Alhucemas to pick up a number of European newspapers which said that the Ketamas were giving the Spanish armies a great deal of trouble and that the campaign would probably result in the withdrawal of the Spaniards! Anything more absurd could not be imagined. The Ketamas had since surrendered, and their country with its thick cedar forests was already being opened up. The Riff was composed of hills with wide valleys, the surface being often a stony character, but much of it could be cultivated and willingly yielded to modern methods, the soil being of a rich red colour. The region inhabited by the Beni Urriaguel and the Bocoya tribes had a good deal of cultivation, but not more than was necessary for the bare sustenance of the people. The Riffs were in the main a wholly uncivilised people; there was no education. During the recent war they had been told about the great Government offices at Abd-el-Krim's capital, but there was no such thing; the place consisted chiefly of simple huts with one good house in a state of ruins. There were no factories and no workshops, and no mosque in the whole of the

Riff. There were zaouias,—Moslem teaching institutions—and a few marabouts, small places used for a minor kind of worship. The men did as little work as possible; they passed most of the time sleeping or talking, and when thoroughly refreshed they fought amongst themselves and also fought other people, such as the Spaniards and French, whenever they had the opportunity. In the Riff the work was done by the women. He did not think he saw any wheeled vehicles except those which belonged to the Spaniards. The women worked in the fields sowing seed and reaping corn, and tending the goats and sheep, and in addition looked after the house. The woman seemed to have no rights. He had a great respect for her because she did all the work, and although she was much neglected she seemed to have a certain pride, especially in an uncivilised people. To be a Riff of the Beni Urriaguel or the Bocoya tribes was to be the very finest kind of Riff; these tribes had a very great pride in themselves which few of the other tribesmen had. They were the élite of the Riff. That was explained by the fact that the men were the richest and the most formidable, gaining in their encounters, and consequently annexing much of the property of other tribes. In wandering through the Riff one could see all over the country specks of yellow and red, which were the women workers in the fields. The women almost universally wore garments of a very brilliant yellow, while round their waists they had bright scarlet sashes, and were always clean and attractive to look at. On their heads they wore kerchiefs very much like the Sicilians. He did not know why they chose such colours in the first instance, but rather suspected the reason was that they enabled them to be seen at a great distance; in the clear light of the Riff it was possible at a distance of three miles to see women working in the fields. The men were very much interested in the women doing a proper amount of work, and in this way they were able to see whether they were working or not. The young women of the tribes, in many cases, had a peculiar grace and charm; and girls of 16 though "uncivilised," were often extremely pretty. The cloth of which their gowns were made came from Manchester. A coincidence was that the yellow and red which they had adopted were the colours of Spain, but, of course, they were not adopted for that reason. With regard to the interest that England had in the Riff, that matter was demonstrated very much during the war. A war in any country concerned every other country.

He should like to say something about communications as showing the work the Spanish had done in a country as difficult for road making as could possibly be imagined, wild mountains, deep valleys, often with very large river beds, rocky and stony. When Spain entered the Riff about nine or ten months ago there were no roads in existence, only tracks which had been made by animals and men. Near Abd-el-Krim's headquarters some sort of very rough roads had been made for a motor car, but they were scarcely roads. At the present moment there were 500 miles of perfect roads, over which he had travelled himself, and he could speak of the quality of the surface because he travelled over them with a military escort in a motor car at 40 miles an hour without difficulty. The minimum width of the roads in the valleys was 22ft., and on the mountain sides 25ft. For 100 to 200 miles the roads ran along the ridges of the mountains, and in one case a descent from a mountain ridge to the valley below was over 3,000ft., and had to be made in a distance of six miles, which meant very quick dropping with an enormous number of hair-pin bends. The 500 miles of roads were splendidly constructed, and there were 300 stone bridges, large and small. Those bridges had all been made in eight months. When the Spanish roads were being made at the end of last summer

25,000 Riffs were engaged in the construction and were working very willingly, being paid a daily wage and their food. The engineer responsible, Captain Gallego, told him that while the Riff was not a fine workman, he had enormous advantages in that country in that the climate did not affect him, and he could work all day on a little bread and water, and the more he worked the better workman he became. There were still 16,000 men working. That indicated the germ of a very great moral revolution in the life of those people. With regard to Alhucemas, which was not so much the name of a town as that of a region, it was a place of entry into the Riff, near the headquarters of Abd-el-Krim. Before the Spaniards entered Alhucemas there was scarcely anything but waste ground with no buildings, but at the present time there was the nucleus of a very considerable Spanish city; there were large Government buildings, a daily newspaper, restaurants and a theatre. The newspaper was a very good one, giving news from all over the world, and it was possible there to read what was going on in London, Paris and New York. The Spanish Government had voted 12,000,000 pesetas for harbour works. The first things landed from Spain and other parts for the improvement of the country were 20,000 trees, which the Riff very badly needed. He thought the port of Alhucemas was destined to be a very important one; shipping there was fast increasing now. He thought there was more than a suspicion in the minds of the Spanish in Morocco that it might supersede Melilla and be the centre of the exploitation of the Riff, which might be a very important piece of territory in the future and one which would have a great deal of money spent upon it. It was of interest to note that the first foreign ship to enter the new port was an English ship—and, incidentally, the second was a German.

LIEUT.-COLONEL E. A. EWART said he did not know that he could add very much to what had been said by the lecturer and Mr. Leach, but he should like to take the opportunity of paying a tribute of thanks and admiration to the Spaniards in Morocco, who were his hosts when he was there about two years ago. He could testify personally, from what he saw himself, to the tremendous work that had been done by Spain in Morocco. The Spanish army there afforded him every possible facility to see over the country, and he availed himself very freely of it. He was foolish enough to hint mildly when he got there that he was pressed for time yet wanted to see as much as possible, and he was taken at his word, and motored from daybreak to dark without a stop. The Spanish proverb said that only Englishmen and horses moved in the sun, but they did not believe that in Morocco. Although in the main his object in visiting the place was to see something of the military organisation and the service conditions, he was also able to see a very great deal of the work that had been described—the work of education, road-making, well-sinking, and the general teaching of the natives to improve their own lot by improved methods of agriculture. It was very impressive to see the women and children in the Spanish hospitals and dispensaries. Very great difficulties were met by the Spaniards in connection with their work, which was done under very adverse conditions, as they had to carry on a war at the same time. During the whole time he was in Morocco with the Spanish troops, looking into the organisation, he saw nothing that would not be a credit to any army in Europe. The work was often carried on near the firing line, which involved difficulties which were overcome in the most remarkable way.

At Monte Arruit there had been a cruel disaster in 1921, the whole circumstances being almost parallel to those of our Indian Mutiny. The European officers had put their trust in native troops and that trust had been misplaced. The garrison was

shut up with a shortness of food and medical supplies, just as in the Mutiny of Cawnpore, and the siege finished with a massacre of women and children. He mentioned this because he had seen an incident which was most creditable to Spain ; within 100 or 200 yards of the graves which marked the spot where the victims of the massacre were buried was a big threshing engine at work, supplied by the Spanish Government to help the natives in the threshing of their grain, and it struck him at the time that here was an indication of the forgiving spirit of Spain, who was holding out the hand of friendship and assistance to the people who were responsible for that dreadful disaster.

H.E. THE MARQUES MERRY DEL VAL, G.C.V.O., the Spanish Ambassador, said at that advanced stage of the proceedings he proposed to be extremely brief, confining himself to expressing his thanks to the Royal Society of Arts for providing an opportunity for making known to the British public the truth about Spanish work in Morocco, and to Sir Charles Bayley for presiding, and also to the lecturer who had so carefully and clearly laid before the meeting all that Spain had done for Morocco, and had illustrated his lecture by photographs which were a material proof of Spain's work in that country. He had also to thank the gentlemen who had nobly come forward to bear witness to the veracity of the lecturer's statements, and it would be noticed that they were both English. He understood that there were several others who had also intended to speak, but on account of the hour they had had to leave the meeting. Those gentlemen were all English, and, indeed, there had been a deliberate intention on the part of the lecturer not to invite the testimony of any but Englishmen as to what Spain had done under great difficulties in Morocco. He thought the lecture would clear up the great fog which had been in part artificially raised, like the smoke screens during the war, in order to hide the machinations of people whose love for Spain was not profound but whose cupidity was much greater.

MR. JAMES CAWSON, in seconding the vote of thanks, said they were all indebted to Señor Baldasano for the lecture and the definite proof he had given of the extraordinary development which had occurred throughout the Spanish zone since the war, and the speech which had been made by Mr. Leach proved also the extraordinary difficulties which must have been experienced by the Spaniards during that war owing to the nature of the country in which they had to operate. The lecturer suggested that at the present moment iron ore was produced, and he should like to know whether there were other ores there also. Reference was also made to the extraordinary development of agriculture generally, and it was mentioned that an endeavour was being made to cultivate the cotton plant. That might in course of time prove to be of enormous value, and it would be interesting if the lecturer could mention what steps had been taken for its development.

The vote of thanks was carried unanimously.

THE CHAIRMAN said the thanks of the audience were also due to both the gentlemen who had spoken in the discussion and had corroborated, if any corroboration were needed, the account given of the work that had been carried on in Morocco. He wished also, on behalf of the Royal Society of Arts, to thank H.E. the Spanish Ambassador for his kindness in being present that day. It had been a great honour, and his remarks had been much appreciated.

THE LECTURER expressed his satisfaction with the remarks that had been made by Mr. Leach and Colonel Ewart, supporting the facts that he had exposed in his paper. It was a real pleasure to him because it showed that he had had the honour of speak

ing before an audience fully acquainted with the Spanish Morocco problem. With regard to the questions asked by Mr. Cawson, he would be glad to give him further particulars, but to enter further into the matter would really lead him into another lecture. He wished to thank Sir Charles Bayley for the honour he had done him for taking the chair, and the Royal Society, with its splendid tradition, for the privilege of speaking before it, and also H.E. the Spanish Ambassador for having honoured the meeting with his presence on that occasion.

The meeting then terminated.

NOTES ON BOOKS.

CHEMISTRY IN MODERN LIFE. By S. A. Arrhenius. Translated from the Swedish by C. S. Leonard. London : Chapman & Hall, Ltd. 15s. net.

CHEMISTRY IN THE WORLD'S WORK. By Harrison E. Howe. London : Chapman and Hall, Ltd. 15s. net.

These two profusely-illustrated volumes are printed in the United States, and form part of the " Library of Modern Sciences " which is being presented to us, on this side, by Messrs. Chapman & Hall. As both volumes deal with subjects of the day from somewhat different standpoints, we can conveniently consider them together.

The author of the first-mentioned work is a worthy and distinguished compatriot and follower of Scheele, Berzelius and Wallerius ; while the author of the second-mentioned work is an American technological writer who has done good service by lucid descriptions and far-reaching generalisations. In the frontispiece of his book Mr. Howe shows us the new method of drawing glass upwards from the pot of fused material so as to form cylinders forty feet high. On p. 128 (Howe) we read of the controlled air pressure and other conditions which make the glass uniform in thickness, and also of the production of flat sheets from the cylinder.

Notwithstanding the varied contents of the two books, our remarks will bear chiefly on a leading feature which is common to both : that immediately important problem of economically converting coal into liquid fuel which can be manufactured at the pit's mouth, then be sent by pipe-line to distant towns for producing smokeless and ashless heating, lighting and motive energy.

Wallerius, who was professor of chemistry, metallurgy and pharmacy at Upsala, is mentioned on p. 256 (Arrhenius) as having, in 1761, given us our first text-book of agricultural chemistry, but of the various treatises written by Wallerius, his *Systema Mineralogicum*, published in 1778, (*Editio Altera Correcta. Vindobonae : In Officina Krausiani*) and including a finely engraved portrait, is of interest as containing a thorough early study of the various kinds of coal, petroleum, asphaltum and products obtained from them by distillation. All this is included in a chapter on the genus *Bitumina*, which extends from p. 89 to 107 in Vol. II of the 1778 edition (Wallerius) mentioned above. Here we have the foundation of that low-temperature distillation which became an industrial feature about the middle of the nineteenth century, largely by the enterprise and skill of James Young (See Reports of the Juries, 1862 Exhibition, printed for the Society of Arts, 1863, Class II, Section A, p. 138. Industry of Distilled Hydrocarbons.)

Dr. Arrhenius, in the first-mentioned of the two books under review, treats of the present-day aspect in the spirit of a profound chemist, and also with the watchful care of the economist. We find on pp. 140-141 the presages of Van Hise regarding the probable failure of the American petroleum supply, the predicted end being in 1935 if there is a normally increasing draft, or in 1953 " with no increase in use."

Dr. Arrhenius generalises on the various aspects of industrial prodigality ; indeed, the whole work may be looked on as an essay in social economy with the alchemist's laboratory (plate opposite p.12) as the old mainspring of energy. In his consideration of catalysts as largely the key to present-day progress, Dr. Arrhenius gives us a first lesson on p. 41, where we find a sketch diagram and description of Döbereiner's lamp, in which hydrogen impinges on a pellet of spongy platinum, and the hydrogen, together with atmospheric oxygen, being condensed upon the metal, union takes place, heat is produced, the spongy metal becomes incandescent, and the jet of hydrogen is ignited. Here we have an old example of catalytic action, but by turning to pp. 183-184 we read of the action of mass and concentration, while Chapter XI, pp. 195-212, leads us to the systematic study of the " course of a chemical process," from the first ionic strain to the ultimate quantitative result. The action of platinum in the Döbereiner lamp bears very directly on a method for the ultra-concentration of oil of vitriol without evaporation ; the gases from a pyrites roasting oven being mixed with air at a temperature of 400° or 500° and then led over platinised iron oxide. Sulphuric anhydride is formed, and this can be passed into the weak acid of the lead chamber ; so the strongest oil of vitriol, the " Nordhausen acid or oleum," is obtained. In this chapter the general action of catalysts is studied in a thorough manner. Thus, for example, a trace of water vapour or finely divided copper may in certain cases act as a catalyst, and although the expensive metal platinum is notable as a catalyst, there is abundant scope and choice. The author's fundamental treatment of his subject, and recent knowledge generally, give great present value to Berthelot's epoch-marking work, *Chimie Organique fondée sur la Synthèse*, which was published in 1860, but when this work appeared, many chemists regarded it rather as a dream or vision than as a realistic effort. Now that this monumental work of Berthelot is bearing abundant fruit, and but few of those who studied it at the time of its appearance can still be working actively with us, it is interesting to open the second volume of Berthelot's work at p. 792, where acetylene seems to take a second place, and carbon monoxide appears as if promoted to the first point in organic synthesis ; Berthelot saying that *l'acide formique engendré par l'oxyde de carbone est la base de toute synthèse*. As regards one notable present-day industrial synthesis by the use of carbon monoxide, the synthesis of methylic alcohol, we may refer the student to the second book under review, pp. 12-13.

Both of the books under review should be read by any person who is interested, and further steps may consist in search and study at our great chemical libraries ; but serious and well-considered laboratory research must be the basis of real progress. The crude and uncertain process of destructive distillation seems likely to give place to definite chemical synthesis both for liquid fuel and gas, but in his library search our imaginary student should pause at and well consider the various reports on special retorts and devices for low-temperature distillation, recently reported on by Dr. C. H. Lander, Director of the Fuel Research Board : these reports being sold at a low price by His Majesty's stationery office. A particularly instructive and suggestive report in this series is one in which we learn how even action of heat with high ratio of liquid products is secured by a revolving retort with internal rumblers : this report, with 1 plate and 6 other illustrations, costing ninenpence (Report of test carried out 1st to 6th July, 1925).

If, on the other hand, strict chemical synthesis should prevail in the near future as against destructive distillation, our standard liquid fuels will probably be definite individual compounds in the paraffin series, rather than mixtures, as now. In the event of this happening, the town gas supplies may move in sympathy, and cast aside those high-temperature destructive distillation methods which have given us

complex and variable mixtures during a century and a quarter. Among the pure or definite hydro-carbon gases likely to be available we may mention propane, olefiant gas and acetylene.

PHOTOGRAPHIC FACTS AND FORMULAS. By E. J. Wall. London: Chapman and Hall, Ltd. 16s. net.

A glance at this book will show how remarkably photographic practice has changed during the past fifty years, or since 1877, when the photographer ordinarily prepared his own sensitive surfaces, and could claim to be a photographer in a very different sense from that which holds good at the present day. We have searched the index of Mr. Wall's volume, and turned over the pages, but have found no instructions for preparing sensitive surfaces for exposure in the camera; whether by collodion or gelatine emulsion.

Nevertheless, Mr. Wall gives exactly what is expected, and generally acceptable at the present time: notes on the work-place, ortho-chromatic photography (which in the broad sense is so treating and using commercial gelatine plates as to make them discriminatively sensitive to colours, according to requirements), exposure, development and after-treatment. Then we have printing processes, and miscellaneous matter, as stereoscopic work, lantern slides, flashlights, and chemical tables, the whole making a ready reference volume for the photographer of our time.

Photographic workers in Great Britain have pleasant recollections of Mr. Wall, who in 1893 was associated with *The Amateur Photographer*, in which he published translations of Dr. Eder's writings on gelatino-haloid emulsions; and Wall's "Dictionary of Photography" has appeared here in many editions since the author left us for the United States. Our authority for stating the volume under notice to be wholly American in origin is on the back of the title-page, where we find the endorsement, "Printed and bound in the U.S.A."

GENERAL NOTES.

BRITISH INDUSTRIES FAIR.—The holding of the British Industries Fair is definitely assured for the next three years, the British Government having leased the White City, Shepherds Bush, for the London section of the Fair for the necessary periods in 1928, 1929 and 1930. The next Fair, which will be held simultaneously in London and Birmingham from February 20th to March 2nd, will be by far the largest British Industries Fair on record. The available exhibition area in London exceeds the space provided there last year by 100,000 square feet. Extensions amounting to 80,000 square feet are to be made at Castle Bromwich, Birmingham, and additional space up to 100,000 square feet is in readiness. Application forms for space in London have been sent out by the Department of Overseas Trade to approximately 10,000 British manufacturers. The space already applied for in the Birmingham section amounts to double the figure for the corresponding date last year.

EGYPT EXPLORATION SOCIETY'S EXHIBITION.—An Exhibition of antiquities, plans, drawings, etc., the result of the past season's work at Tell el-Amarna, will be held in the Society's rooms at 13, Tavistock Square, W.C.1, from July 5th to 22nd (including Saturdays), the hours of admission being from 10 a.m. to 5.30 p.m. A lecture illustrated by lantern slides, on the same subject, will also be delivered by M. Henri Frankfort, M.A., Director of Excavations, in the meeting room of the Royal Society, Burlington House, at 5.30 p.m., on Thursday, July 14th. Admission is free, both to the Exhibition and Lecture.

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All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2.)

NOTICE.

ANNUAL GENERAL MEETING.

WEDNESDAY, JULY 6TH, 1927. SIR THOMAS HOLLAND, K.C.S.I., K.C.I.E., D.Sc., F.R.S., in the chair. The one-hundred-and-seventy-third Annual General Meeting of the Society was held for the purpose of receiving the Council's Report and the Financial Statement for 1926, for the revision of the Bye-laws, and also for the Election of Officers and new Fellows.

A full report of the Meeting will be published in the next issue of the *Journal*.

PROCEEDINGS OF THE SOCIETY.

FIFTEENTH ORDINARY MEETING.

WEDNESDAY, MARCH 16TH, 1927.

SIR FRANK BAINES, C.V.O., C.B.E., Director of Works, H.M. Office of Works, in the Chair.

THE CHAIRMAN, in introducing the lecturer, said Dr. Wheeler was known to a great many of the audience. Until recently he had been Director of the National Museum of Wales and he was now Keeper and Secretary of the London Museum. Dr. Wheeler had a distinguished record in archæology; he had done most important work on the Royal Commission on Historical Monuments, and he had been a lecturer on archæology in the University of Wales. He was also a member of the Ancient Monuments Board for Wales, and had been responsible for many highly important excavations, such as that which was now being conducted at Caerleon.

Personally he had had the privilege of understanding in part the principles which had guided Dr. Wheeler in conducting excavations into historical sites, as he had been in charge of the work at Caerwent where Dr. Wheeler had given

most precise and definite instructions with regard to the excavation of that important historical monument.

He thought all would agree that the title of the lecture was an intriguing one. It seemed to imply a plunge into the mazes of history by a path such as would definitely involve the laying down of a new technique. These present would hear an elaboration of that new technique, which, to his own knowledge, was hardly on complete record anywhere. History by excavation involved very definite demands on the archæologist, because the archæologist was not in a position to know whether he was going to discover coins or pottery or other things; he had to have a most complete knowledge of historical objects of all classes and kinds and of all dates; he had to have a very strong and definite opinion as to the nature of proof; he had to be able to form a judgment as to the evidential value of his finds; he had to have a complete sense of accuracy above all things; and when he reached certainty, it had to come to him based on a very complete archæological and historical knowledge. The archæologist, too, had to interpret material facts, and there the widest demands were made upon the archæological equipment of those investigating and excavating sites of supreme national importance. The archæologist also had to weigh the normal law of probability, examine generally accepted facts and make just deductions. For example, one of the generally accepted facts in history was that, as the Saxons were known to have erased the Romano-British, it seemed more than probable that Silchester and other Roman towns which were found to have been burned had been in fact destroyed by the Saxons. Such deductions were really based upon detailed knowledge, although the historian acting by excavation must preserve a completely open mind on all obscure points.

The great value of archæology was that it was possible for it to delay its decision. Finality was not demanded necessarily at the time of any specific work. Obscure points could be given greater weight than in almost any other science; but it was clear that when definite demands on the interpretation of an historic site were made, this new technique called for a very special form of training and knowledge. It called for a remarkable completeness of archæological knowledge which was probably not called for in any other sphere of the kind. That imposed upon everyone interested a necessary duty, namely, that of seeing whether or not there could not be provided an opportunity for training men who would be enabled, by experience and by training under archæologists such as Dr. Wheeler, to launch out on this very difficult new technique of history by excavation. After all, as a people to-day we treasured old things more than any other people of past ages, and yet, in looking around us and seeing the things with which we lived, what an insignificant and small proportion of old and beautiful objects were comprised in our possessions of to-day. There was the rarest recurrence of old objects, and their discovery, therefore, was an important and vital fact of history, requiring perfect scientific record. Excavation carefully conducted showed us the history of sites and gave us particulars of their repeated occupation; but sites had to be read very differently from other historical documents. There was the evidence of midden heaps, quite special in themselves; there was the evidence of burned sections; there was the evidence of cataclysmic events, and lastly there was the evidence of style. The archæological equipment demanded for the reading of all such evidence was immense, and if only the records which we had of the excavation of sites were complete, we should get a very marvellous insight into the history of the past of this country, which he looked forward to hearing more about from Dr. Wheeler.

DR. WHEELER then delivered his lecture, of which the following is a summary:—

HISTORY BY EXCAVATION.

By R. E. MORTIMER WHEELER, M.C., D.Lit., F.S.A.,

Keeper and Secretary of the London Museum.

St. Augustine once declared : " It is better to dig than to dance." I have not come to defend a sentiment so remote from the progressive thought of to-day ; although it might not be altogether heretical to maintain that digging, in the archæological sense, at least rivals modern dancing in complexity of procedure. There is, however, no longer need for a defence of scientific excavation. The British public, through the action of its Ancient Monuments Acts and through countless public and private organizations of varying capacity, is now committed irretrievably to the patronage of archæology. It is to-day the proprietor or guardian of historical or archæological relics and structures on a very large scale—a responsibility which has been rapidly increased during the post-War years by the breaking-up of large estates and by other economic exigencies. Simultaneously the cheap motor-car has enabled the general public for the first time to discover its own countryside and its own antiquities. I have recently seen omnibuses run " To the—excavations," and 2000 people—members of the ordinary holiday-making public—visited the site in a space of three days. This new interest is reflected in and encouraged by the daily press ; nay, the daily press has itself taken up archæological exploration, and one London newspaper has just spent no less than £2,500 on work of this kind. Lastly, archæology is beginning to percolate slowly through to our universities and to our public schools, and even to form innocuous pools of somewhat colourless knowledge (mostly a refined Darwinism) in which our kindergartens are encouraged to paddle. In short, the public is interested to the extent of active curiosity, and is distinctly anxious to know something of the ways and means of archæological discovery, and of the activities of its archæological agents.

For public ownership of antiquities obviously implies a public administrative machine with an expert archæological and architectural staff. Now, in Whitehall the picker-up of unconsidered trifles of this kind is the Office of Works, and it is upon our distinguished Chairman, in collaboration with a special Ancient Monuments Department under Mr. C. R. Peers, that the responsibility of safeguarding our National Antiquities devolves.

Less busy men than Sir Frank Baines and his colleagues would find their time more than occupied by this problem alone. Let us glance at a single instance. An ancient building of historical and artistic importance is handed over to the nation as a " national monument." Its walls are crumbling and are probably riven asunder by tree-roots and ivy. These have to be cleared away and the walls strengthened without in any way altering or, in the Victorian sense, " restoring " the broken masonry. With that difficult work I am not

now concerned. But that is only one part of the problem of rehabilitation. In the course of centuries, the ground-level round about the structure has steadily risen until it has obscured or even completely buried some of its most important features (Fig. 1). This process has been due to various causes. Some of it is the result of the annual decay of vegetation ; some of it has been rain-wash from elsewhere ; much of it is the handiwork of man, either in the form of *construction* or in that of *destruction*. In this accumulation lies buried much of the history of the site. It cannot be disturbed without disturbing



FIG. 1.—The Caerleon amphitheatre : one of the main entrances in process of excavation, showing the fallen voussoirs of the Roman arch lying in an accumulation of 12 feet of earth and débris.

and destroying historical or archæological evidence. The work of clearing an ancient structure is thus a work of excavation which, carried out scientifically, will add to the history of our land, and, carried out *without* science, will destroy for ever something of our inheritance. The means whereby this work is carried out are, in theory, simple, though less simple in practice, and I am asked to-night to illustrate some of them with reference to typical investigations.

To many members of my audience the technique of archæological excavation may be familiar. From those I would crave patience if I explain at the outset that the key-word of excavation is *stratification*—a term which means nothing more or less than the relationship of one object to another, or of one deposit to another, in the soil. Let me give a simple instance, not from the handiwork of man but from that of nature.

One of the most vital episodes in the story of European man is that which was marked by the final withdrawal of the great ice-fields from most of central and north-western Europe, and the advent of geographical and climatic conditions substantially akin to those of modern times. With the departing snows seem to have disappeared the last vestiges of an exotic and (to our eyes) amorphous Europe which had for long ages been the hunting-ground of successive animal and human species now largely extinct. The date of this tremendous metamorphosis has long been the subject of conjecture, often of the most extravagant kind; and the general tendency has been to ascribe it to an almost unimaginably remote period. The point is of more than academic interest, since it is now possible to trace in outline stage by stage the main succession of human types and cultures in western Europe almost continuously from the end of the glacial epoch to the present day, and to date the end of the glacial epoch is in effect to date the beginning of the development of modern civilization in Europe. It was therefore a sensational moment when Swedish geology claimed to have set a term to guesswork in this matter by reference to the banded clays of Sweden (Fig. 2.) These clays represent the miscellaneous



FIG. 2.—Banded clay, representing annual deposits left by the melting ice-field near Uppsala.

material deposited from the melting ice each summer around the fringe of the retreating ice-field in a slowly ameliorating climate, and their succession from the south to the north of Sweden has been compared aptly to that of overlapping slates on a roof. It is clear that if these annual deposits (which have been going on to the present day) can be counted accurately from south to north they will provide something like a time-table for the retreat of the ice in Scandinavia. On this premise, Baron de Geer has estimated 12,000 years as the period since southern Sweden first became habitable, and his view has been widely, if not universally, accepted. For our present purpose it will suffice to note that these banded or stratified clays illustrate, in the simplest and most literal form, the principle of definite chronological sequence represented by the superposition of stratum over stratum in the soil. This principle lies at the basis of all archæological excavation.



FIG. 3.—Palæolithic painting of a bison, from the ceiling of the cave of Altamira in Northern Spain. (*After Breuil.*)

I now turn for a moment to a series of well-known discoveries wherein scientific excavation has combined with other evidence during the past thirty years to throw a new light upon the civilizations of France and Spain at about the time when the ice-fields, to which I have alluded, were in the earlier phases of their withdrawal. The first of these discoveries dates from 1879 when a child, who accompanied her father into the now-famous cave of Altamira in northern Spain, noticed paintings of bison on the rocky ceiling of the cave (Fig. 3). The announcement of the discovery was greeted with incredulity, and although many of the pictures represent animals long extinct in western

Europe, it was not until many years afterwards that the remote antiquity of these and other paintings of the same kind was established beyond doubt by excavation. Briefly, the results of excavation were these. In the first place it was found that in some cases the paintings or drawings on the walls of the caves were covered by accumulated strata containing implements exclusively of Old Stone Age type and clearly representing the *débris* of occupation in that period. Secondly, fragments of bone and stone bearing engravings similar to those on the cave-walls were discovered buried in these stratified deposits and obviously belonging to them. And, thirdly, caves containing wall-paintings were in some cases blocked in ancient times and the blockings covered with *débris* (in position) representing a superimposed occupation still within the Stone Age. In result, the main period of one of the most striking phases of ancient art has now been established and, on de Geer's chronology, we may say that round about 15000 B.C. there were in western Europe schools of artists whose work at its best, for delicacy and vividness of observation, has scarcely been excelled.



FIG. 4.—Section through the successive floors in one of the huts of the Glastonbury lake-village. (From Bulleid and Gray, *The Glastonbury Lake-Village*.)

We will now pass on to the extreme end of the prehistoric era—to an example taken from a British site which was occupied for a century before and after the brief raids of Julius Cæsar upon this island. I refer to the celebrated marsh-village of Glastonbury in Somerset. The photograph which I show you next (Fig. 4.) might indeed be taken as a standard example of “stratification.” It represents a section through the hearth of one of the rough circular huts which were built on piles driven into the marsh. On this uncertain basis the hut-

floors tended to sink, and both for this and for other reasons the clay hearths were in many cases renewed more than once—in the present case, three times. The thin black lines which separate the renewals represent the charcoal and other débris which accumulated on each successive hearth, and it is sufficiently clear that the relics found in these layers, if carefully grouped layer by layer will constitute an index-series illustrating something of the culture of the settlement in correct chronological sequence. They are potentially fraught with a significance akin to that of historical documents ; at least they enable us to reconstruct in something more than outline the developing environment wherein, age by age, our unrecorded history was enacted.

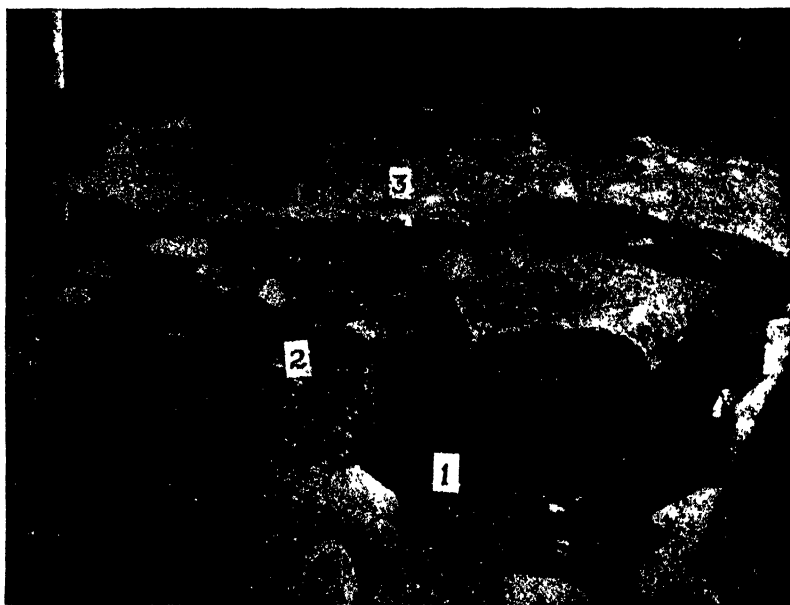


FIG. 5.—Section through the roads of the N.W. entrance of the Roman fort at Carnarvon, showing three successive levels, with a damaged column-capital thrown into the "make-up" of the third (latest) road.

My remaining examples shall, with one exception, be taken from Roman sites, on which so much work has been accomplished in recent years with results which have not merely added very materially to our knowledge of Roman Britain but have incidentally done more than any other thing to develop in this country the technique of archaeological excavation. From the embarrassingly abundant material I select four examples, each of a somewhat different kind.

My first is a particularly simple one, yet one which is eloquent of unwritten history. It represents a cutting across a Roman road where it passes between the guard-towers of the Roman fort at Carnarvon. (Fig. 5). It will be seen that the roadway is really three roads, one superimposed upon another. Each

is of iron-hard road-metal, built, in characteristic Roman fashion, for all time. Now in the process of excavation each of these roads was peeled off separately and with scrupulous care, and the relics which each contained were segregated and examined. The two lower roads were found to coincide with the building and rebuilding of the fort during the earlier periods of assured and leisurely Roman settlement. The last and uppermost road told a different story. Into



FIG. 6.—The Roman fort at Carnarvon: the cellar or strong-room in the headquarters building after excavation. (From *The Journal of Roman Studies*.)

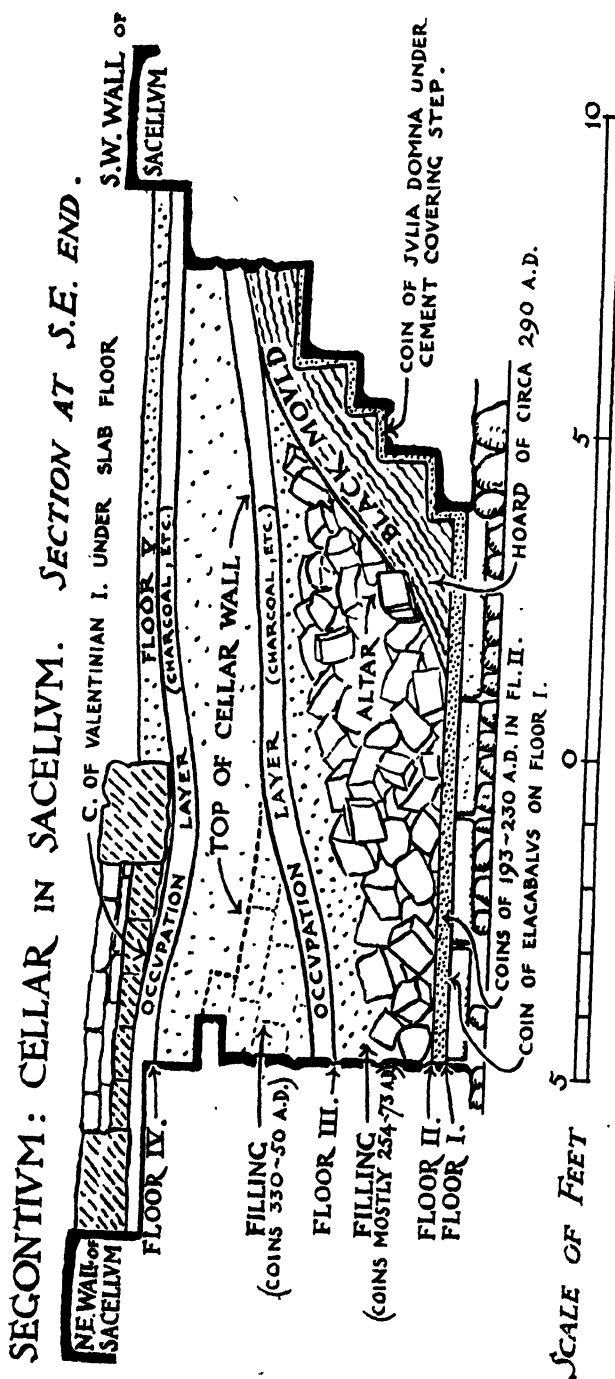


FIG. 7.—Section through the Roman cellar at Carnarvon, showing the position of relics and deposits which enabled the excavators to reconstruct the main features of the later history of the fort (From *Archæologia Cambrensis*, 1922.)

it were thrown the battered columns and building-stones of a fort which had been destroyed or utterly neglected—vivid witness to a period of anxious reconstruction in a time of urgent re-occupation. With the columns beneath the road-surface lay a number of those small and almost worthless coins which were yet sufficient to shew the period of the work and thus to indicate its cause. The reconstruction was of late 4th century date, carried out therefore amongst the last despairing acts of the Roman Command, harassed on one flank by the Saxons and on the other by the Irish, and with the Picts of Scotland upon its back. The fallen column seen in the photograph, covered by the last of the Roman roads, is a landmark in the history of Britain.

From the same Roman fort at Carnarvon I take another example. In Fig. 6. is seen the cellar or strong-room built for security within the regimental shrine of the fort; Fig. 7. shows a section across this same cellar as revealed during the process of excavation. This instructive section is replete with the early history of western Britain. Silver coins of early 3rd century date in the floor of the cellar show that it was built during the great military revival which accompanied and followed the visit of the emperor Septimius Severus to Britain—the emperor whose dying effort to subdue Scotland represents the last attempt of Rome to complete the conquest of these islands. The death of Septimius at York in 211 was followed by a century of intermittent bloodshed, and the fort was then abandoned. Earth drifted through the doorway of the strong-room and thickly covered the steps, as can be seen in the drawn section. With the steps it covered a smashed money-box and a hoard of coins—scattered and forgotten in the hurried departure of the garrison. Later, in the last stand to which I have referred above, the fort was reoccupied and rebuilt, the cellar was filled up with an altar and the débris of ruined buildings and covered by new floors which were themselves subsequently renewed. Coins and pottery show that, as at the gateway, this period of drastic reorganisation fell within the last half century of Roman rule in Britain, when the Scot from Ireland was, in the words of Claudian, “moving all Ierne to arms, and Ocean whitened under the oars of invaders” intent upon the coasts of the Roman province.

I turn now to a somewhat different illustration of the significance of stratification in relation to structural remains. I emphasise this example because it is the imperfect understanding of the principle involved that renders amateur excavation such a danger to the cause of scientific knowledge. Once again the principle is, in theory, simple, and it is this. The builders of a wall will normally begin by digging a trench through the comparatively soft humus down into the more solid underlying strata. The bottom of this trench they will pack with stones, with or without mortar, to form a solid footing. On this firm footing the faced walling is then erected. Now if the site of the structure has been occupied previously, we may expect to find the natural soil covered with one or more “occupation-layers,” or

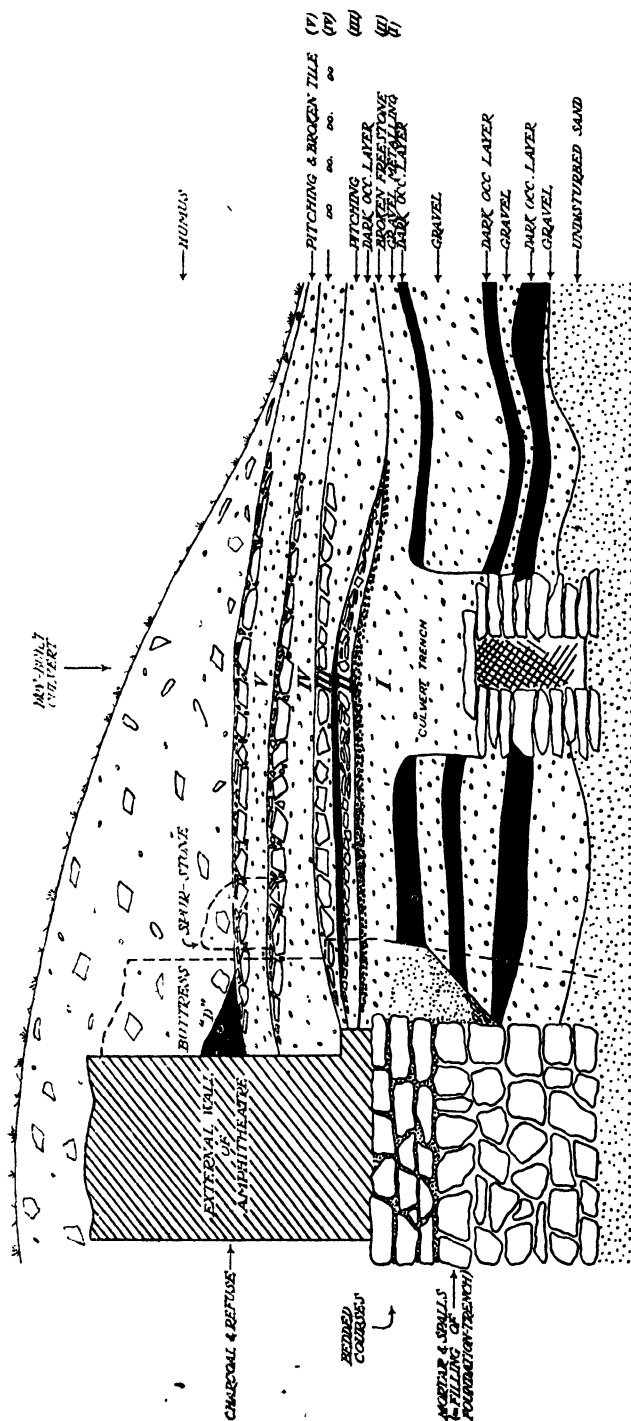


Fig. 8.—Caerleon Roman amphitheatre: section through external wall and adjacent road on the south side, showing the lower strata cut through by the builders of the amphitheatre and the higher strata (road levels) laid down during or after the construction of the amphitheatre.

V.E. NASH-WILLIAMS, 1926.

deposits of *débris* and other materials which inevitably accumulate upon ground occupied by man. Moreover, when the walled structure is built and itself occupied, further occupation-layers will begin to form in association with it. The first problem which confronts the archæologist is therefore clear; it is to distinguish between the layers which were *cut* by the builders (and therefore antedate the structure) and those which are *contiguous with* the faced walling and are therefore contemporary with or subsequent to the work of construction. If stratified relics can be found to date the last of the *pre-constructional* deposits on the one hand and the first of the *post-constructional* deposits on the other, then the date of construction on a continuously occupied site may be inferred with double certainty. Figure 8 shows this principle at work.

In this illustration the wall in section is that which surrounds the Roman amphitheatre at Caerleon—a monument recently presented to the nation (through the generosity of the *Daily Mail*) and therefore well known to our Chairman. It will be seen that this wall is built upon deep footings, the upper part of which is mortared whilst the lower part is dry-built. The footings occupy a trench cut through three dark occupation-layers which therefore antedate the construction. We then come to the faced walling, the base of which is in contact with a road surface laid down clearly in connection with it; and this road-surface was renewed at several subsequent periods during the life-time of the structure. Now the pre-constructional deposits contained 1st-century remains; the post-constructional roads on the other hand failed at this point to yield definite evidence. Here, however, another factor came to our rescue. It will be seen from the section that, to the right of the wall, a culvert was built in a trench cut through the same strata as those penetrated by the footings of the wall, and that it also was covered by the road-surface contemporary with the construction of the wall. It is therefore also contemporary with the building of the amphitheatre. Further exploration then showed that the culvert was structurally connected with a neighbouring bath-building dating from about the end of the 1st century A.D. It follows that the amphitheatre is also of this date; its lateness in the century being confirmed by the fact, already mentioned, that more than one occupation-layer of the latter part of the 1st century preceded its construction.

Thus, both directly and indirectly, it is obviously of vital importance to note with scrupulous care the relationship of strata to structure—whether the strata are contiguous and contemporary, or whether they are cut by the structure and precede it. Yet the first instinct of the inexperienced excavator when he discovers a buried wall is at once to cut alongside it in order to see where it goes to! Thereby destroying beyond amend just that evidence which might have made his discovery a real and living addition to knowledge instead of a mere dead and unintelligible “curiosity” of comparatively little value.

One more example of structural evidence from another Roman structure

which has come within our Chairman's extensive province—the south wall of the Roman town of Caerwent in Monmouthshire, a wall that is one of the most striking pieces of Roman masonry in the country. It still stands to a height of 20 feet, and is backed by a great earthen ramp some 40 feet broad. The extent of this ramp gave rise in my mind to some wonderment, for it was (i) clearly placed in position after the building of the wall, which was certainly constructed “free”; (ii) there is only one small gate in the long length of the wall; (iii) the earth was clean and obviously brought from outside the town; and (iv) the labour of carting thousands of tons of earth through a single small gate and of distributing it along some 200 yards of wall in each direction seemed at least an uneconomical proposition. We—Mr. V. E. Nash-Williams being the other



FIG. 9.—Inner side of the south wall of the Roman town at Caerwent, Monmouthshire. The Roman bank which supplemented the wall has here been removed temporarily to show:—A, The faced wall, built free, before the addition of the bank; B, The “plugging” in the gap left for the introduction of the earth for the bank; C, The faced wall carried up free above the level of both bank and “plugging.”

member of the partnership—looked for, and found, another solution of the difficulty. At three points along the wall the builders had left rough gaps for the transport of the earth, and in one or two places had actually laid rough roads through the openings. The earth had then been brought in (possibly in mule-panniers) and placed in position until finally it closed the gaps on the inside. The openings in the wall were then plugged with masonry from the outside, and the wall finished off. The photograph, Fig. 9, shows clearly the difference between those parts of the wall which were built “free” and brought

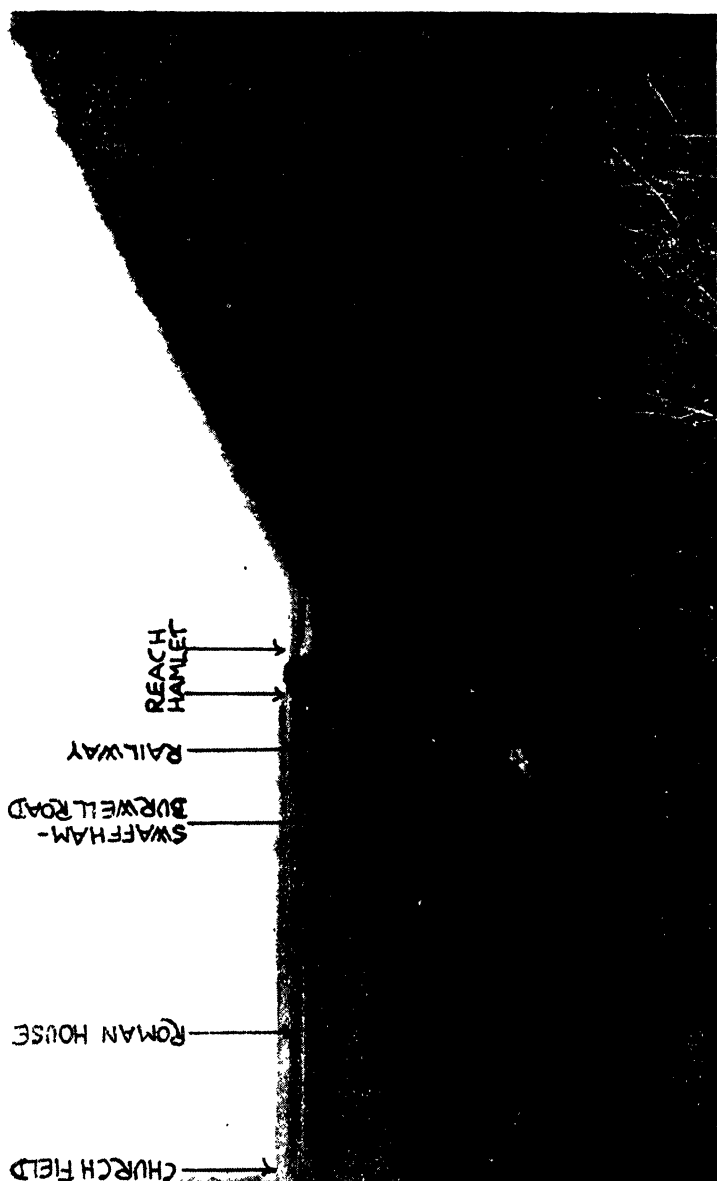


FIG. 10.—General view of the Devil's Dyke, Cambridgeshire, looking N.W. from Gallow's Hill.

to a face prior to the deposition of the earthen ramp, and the central patch of rough masonry built in from the outside against the ramp when in position.

In this and in other ways which may be omitted from the present summary, excavation has enabled us not merely to find out something of the period in which the imposing defences of Caerwent were raised, but to reconstruct the

methods employed by the engineers and workmen and to re-create a human picture of an episode which, with its far-reaching implications, must have meant much in the lives of the Romano-British inhabitants of the west.

A last example I take from the work of Dr. Cyril Fox upon one of the dykes of Cambridgeshire—an example which illustrates the only effective method whereby the problems of these great “running” earthworks have been tackled by the spade. The casual trenching of earthen banks, erected as defences or boundaries across many miles of country, obviously cannot be expected to yield (save by the merest chance) any significant information in regard to their date and historical environment. The problem therefore presents difficulties of a kind which do not as a rule confront the archæologist on ancient occupation-sites, where the débris of a former resident-population may be expected to provide evidence of period and “culture.” In approaching the problem of the Devil’s Dyke, north-east of Cambridge, Dr. Fox was faced with two main questions: (1) What was the strategic purpose of the Dyke? and (2) Was it a prehistoric tribal boundary, a work of the Roman era, or a relic of the Anglo-Saxon epoch?—all views which had found advocates at one time or another.

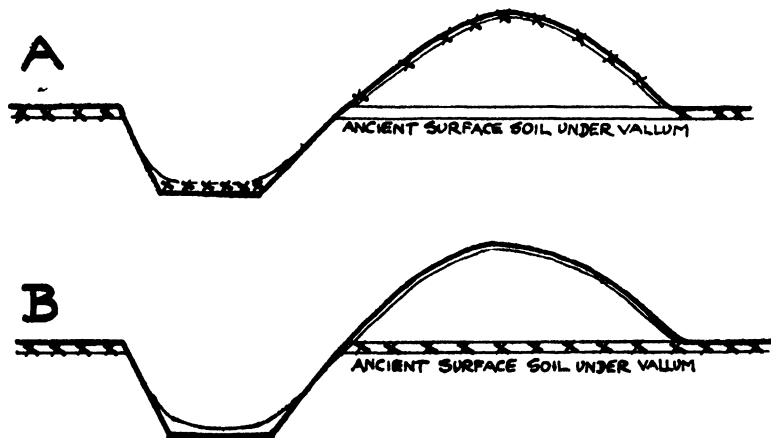


FIG. 11.—Diagram of earthwork adjoining a Roman site, showing theoretical position of Roman objects (XXX) in relation to:—(A) a pre-Roman earthwork, and (B) a post-Roman earthwork.

The strategic problem presented no great difficulty. The series of defensive banks, of which the Devil’s Dyke (Fig. 10) forms one, bears little or no relationship to the present topography of the district; the banks begin and end “in the air,” without apparent purpose. An examination of the drift-map, however, supplies the explanation. To the south-east the banks end as they reach the clay—i.e. at the point where, under pre-agricultural conditions, the dense oak-forest began. At their north-western ends they stop on the margin of the natural fen-land. They were thus built as barriers across the open space which intervened between the former natural obstructions of fen and forest.

The chronological problem was less easy. It was partially solved as follows. At one point close to the dyke are known to exist the remains of a Roman house, and the surrounding land is, as usual in such cases, littered with fragments of Roman pottery and other débris. The relationship of this débris to the neigh-



FIG. 12.—Section through the Devil's Dyke, Cambridgeshire.

bouring dyke seemed likely to provide the missing clue ; for if the *débris* was already in position when the dyke was built, a trench should reveal it on the old land-surface beneath the structure of the dyke ; whereas, if the latter was built first, the *débris* would presumably extend over the surface of the mound and would be absent from the underlying soil. The alternatives are represented graphically in Fig. 11, which, with the following illustrations, is reproduced by the courtesy of the Cambridge Antiquarian Society.

Of these alternatives, the first was proved by excavation, as shown in Figs. 12 and 13. On the former surface below the substance of the mound were found much-worn fragments of Roman pottery of 2nd or 3rd century date (Fig 14) and, apparently, a late 3rd century coin. The building of the mound or dyke was therefore subsequent to this period, and must be ascribed either to a late Roman or to a post-Roman date. Of the alternatives, the latter is the more probable and is supported by the worn condition of the underlying Roman objects. It may be added that similar methods have yielded similar results in the case of Offa's Dyke in Flintshire.

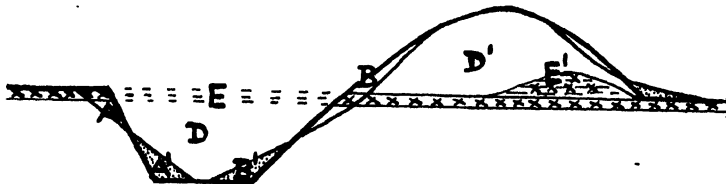


FIG. 13.—Diagrammatic illustration of results of section through the Devil's Dyke. E is original surface-soil transferred to E' by the builders of the Dyke to mark its intended limits. D is chalk rock transferred as chalk rubble to D'. A and B represent material on counterscarp and scarp respectively transferred by natural denudation to the fosse at the points A' and B'. The position of Roman relics is indicated by XXX.

I have now illustrated the guiding principle of archaeological excavation as embodied in the word "stratification." At the outset, I suggested that public interest in the matter was no longer confined to the leisured dilettante. The public as a whole, I would repeat, are now proprietors or guardians of archaeological sites on a large scale and, in one way or another, it is their privilege to pay the bill for the upkeep of these store-houses of their history and their traditions. The responsible task of safeguarding these national monuments is, we know, not merely in safe keeping but is without question more brilliantly fulfilled in this country than in any other country in Europe at the present time. It would be easy, therefore, at first sight for the British Public to make light of its collective responsibility in the matter.

At no time in our history, however, has a collective sense of responsibility in regard to our antiquities been more acutely necessary. The surface of our land is changing, and changing rapidly. The breaking-up of large estates, to which I have referred, has, indeed, led to the acquisition of some of our more important historical monuments by the State. But in many cases, it has led

ancient and historical buildings into dangers from which they have hitherto been exempt. The small landowners, or the impersonal syndicates, who are now replacing the large estate-owner of pre-war days, are under necessity of developing or exploiting their newly acquired property. New suburbs are springing up round most of our towns. New roads are being built and old ones widened. Some of our most beautiful bridges have been demolished and others are threatened. I need not extend the catalogue of perils which now encompass our inheritance from the past. *Progress* in itself is a good and necessary

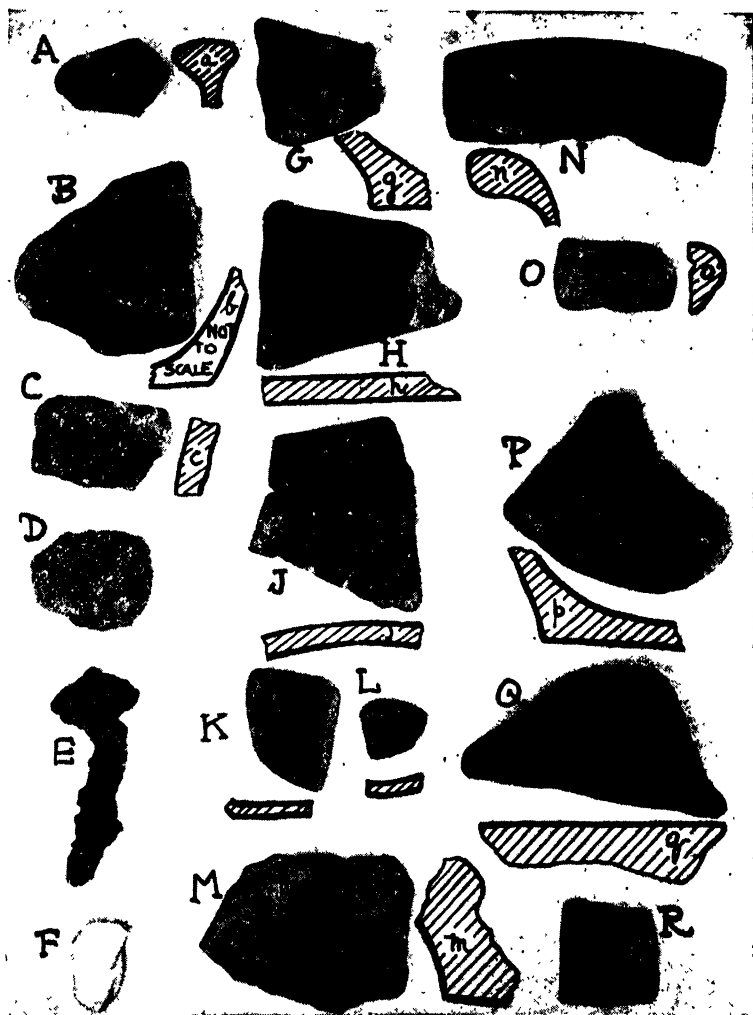


FIG. 14.—Fragments of weathered Roman pottery found in such a position under the Devil's Dyke as to show that they were present before the Dyke was built. In spite of their apparent insignificance, they are, therefore, of high historical value.

thing, and it is, indeed, to progress in the past that we owe many of our most valuable historical monuments. But in a small and crowded country like ours, the utmost care and consideration are necessary on the part of every one of us, if we are to prevent ourselves from converting reasoned progress into a blind or hasty devastation of the great fabric which our forefathers so well and truly wrought, and on which our own creative efforts are after all based. I have to-night attempted to show that the history of our country and of our civilization is built up not merely in our documents, nor even in the bricks and mortar of our ancient buildings, but that it is enshrined also in the soil which may on its surface bear no visible vestige of antiquity. The responsibility of safe-guarding this historic soil lies, in the first instance, not with a few harassed officials in Whitehall but with the great public as a whole. A general knowledge of the guiding principles of historical and archaeological research is not expected to turn us into a nation of scientific historians or archaeologists, but it will at least do something to bring home the importance of archaeological material and so to stay the hand of unguided exploration or destruction. We have our National Public Record Office in Chancery Lane ; but it is worth remembering that we have a still vaster record office in our countryside. And we are, each and every one of us, its guardians.

DISCUSSION.

MR. GEORGE H. DUCKWORTH, C.B., F.S.A. said he had listened to Dr. Wheeler's paper with great pride and pleasure. Dr. Wheeler was still a young man, and he had been a still younger man when he had first been connected with his (Mr. Duckworth's) Royal Commission on Historical Monuments. He thought the audience would agree with him when he said that what Dr. Wheeler had learned there had in no way prevented his development along most interesting lines of archaeological enquiry. Dr. Wheeler had taken his audience that evening back to 12,000 B.C. in connection with Sweden, and he had also exhibited the picture of a bison, which took them back 3,000 years earlier. Personally he wanted to take Dr. Wheeler back 15,000 years earlier still—in connection with the caves at Malta. He had been at Malta two years ago, when it had been explained to him that Malta had in the distant past been part of a bridge between Africa and Europe, with great lakes on either side of it. At certain periods there had been a falling of the land on either side of what was now the island of Malta, and inundations. With each inundation the animals had sought refuge in those caves. Mud had overwhelmed them, and on top of each deposit of mud a leaf of white stalagmites had been formed in such a way that one could go back to 30,000 years B.C. He did not know whether Dr. Wheeler would confirm that, but to him it had been a most interesting example of history by stratification.

DR. ARTHUR HAYDON drew attention to the excavations which had been made in the rocks at Gibraltar, and said that it was noteworthy that the same variety of monkey as was discovered in the rocks of Gibraltar also existed on the other side in Africa.

MR. REGINALD A. SMITH (British Museum) said it had been very refreshing to listen to Dr. Wheeler's experiences in the field. Luckily for himself, and for all

those interested in the subject, Dr. Wheeler had had the leisure and opportunity to pursue those excavations. The only regret was that there were not more young men in this country to follow in Dr. Wheeler's footsteps, and to take charge of excavations which were calling for attention. He believed that Dr. Wheeler had a scheme in mind for founding in London a sort of school or institute for training young archaeologists, especially in field work. That could be done, but of course it would require funds and management. Whether Dr. Wheeler was as capable of raising funds as he was of inculcating the principles of excavation, he could not say; it remained for the future to discover that, but he wished Dr. Wheeler all success in any attempt to make archaeology a national movement. Schemes for excavating here, there, and everywhere would have to be properly checked and managed. One heard from time to time of small farmers for instance, finding pieces of Roman pottery in their fields and digging near the centre of the distribution. Usually they came across walls, bits of plaster, and so on, and dug them up without any record at all, until they were tired of it. That was a thing which ought not to be encouraged. If at some central institution one had news of such things occurring, it was evident that a large staff would be necessary to superintend and advise on, and, if necessary, to excavate, all those sites which came to light. He did not wish to accuse the farmers of any sordid motives, but their native curiosity prompted them to go and dig on their own lands superficially, and the existence of motor car and charabanc parties made it quite possible, if they did find a Roman villa on their land, for them to recoup themselves for any expense in the excavation. That sort of thing ought to be checked, and he sincerely hoped that Dr. Wheeler would be able very shortly to found an Institute which would provide the staff to organise such excavations.

MR. ROBERT GARRAWAY RICE (Vice-President, Society of Antiquaries) said he fully agreed with Dr. Wheeler's advice to pay great attention to stratification. Whatever material was being dealt with, stratification formed a very useful principle to follow. By following out the system which had been so admirably explained that evening every excavation ought to yield something to present-day knowledge of the subject.

MR. G. ELLIOT ANSTRUTHER said Dr. Wheeler had mentioned that, when the excavation of the amphitheatre at Caerleon was completed, that amphitheatre would be the only one visible in this country. Did that mean it would be the only one visible because it was not possible in some way to make visible the other amphitheatre which he understood still existed on the site of the ancient town of Verulamium, within 20 miles of London? It might be that the remains at Verulamium were not comparable in interest to those which were being excavated at Caerleon, but it was interesting to him as a Londoner that within 20 miles of London a Roman amphitheatre existed.

DR. WHEELER, in reply, said that at Verulamium the theatre had been uncovered many years ago and had been covered up again. Verulamium would prove at some time or another the richest site of its kind in Great Britain. It was very fortunate that its excavation had not hitherto been attempted, because one could look forward now to its excavation at a time when British archaeology would have not only ample information from other sites in the country upon which to go, but would also, he hoped, if his and Mr. Reginald Smith's dreams came true, have adequately trained professional staffs for the purpose. The amphitheatre at Caerleon happened

to be the only amphitheatre in Great Britain at present uncovered and therefore visible approximately in its original condition.

With regard to the caves in Malta, that lay a little outside the scope of the paper, but the bearing of Mr. Duckworth's remarks upon them was, briefly, that the further south one went the earlier one had to place the beginning of the withdrawal of the glaciers. For instance, in the north of Germany, the glaciers must have begun to withdraw many thousands of years earlier than in the south of Sweden, and a period of five thousand years had been guessed as the additional period required. The period of the beginning of the withdrawal of the icefields in the north of Germany had been estimated at roughly 17,000 years ago. Further south, as far south as Malta, one got beyond the scope of the icefields, and other conditions came into account. In regard to the actual details of the caves at Malta, they were of extraordinary interest. They had been examined very carefully and scientifically by Dr. Zammett, who had published the results of his work there; but as to the date of the earliest remains to which Mr. Duckworth had referred in his interesting remarks, he was afraid he could offer no valuable opinion.

The question of the presence of certain fauna in Gibraltar was easily explained when one recalled the fact that there had been a land bridge at Gibraltar across to the western end of the Mediterranean in comparatively recent geological times. Most of the great seas, such as the Mediterranean and the Baltic, had undergone fluctuations of level in relatively recent times. At more than one period the Baltic, for example, had been alternately a lake and a sea. Great Britain had been alternately joined to and separated from the continent. The same was the case with the Mediterranean. Lands which were now widely separated by water had been at various geological periods joined together. Therefore the fauna had been able to go from one part of the world to another over spaces which at the time had consisted of dry land.

Finally, he might be allowed to reaffirm Mr. Smith's reference to a matter on which he had not intended to touch that evening, but which was very near to his heart, namely, the question of the centralisation of British archæology and the provision of adequate training for archæologists. In a nutshell the problem was £70,000, the sum required for the creation and permanent endowment of an efficient school of British Archæology.

THE CHAIRMAN, in moving a hearty vote of thanks to Dr. Wheeler for his extraordinarily interesting paper, said that to himself, as one connected to some extent with the work of preserving historical monuments, Dr. Wheeler conveyed an entirely fictitious sense of ease with regard to the work of excavating historical sites. Dr. Wheeler showed by his pictures and by the clarity of his exposition that it really was a matter that could be undertaken and definitely brought to success; but personally he desired to give a solemn warning that the excavation of historical sites was a problem of extreme difficulty. The problem was so difficult that one might do irretrievable harm by excavating in the haphazard and light-hearted spirit which had been perhaps the mode of tackling excavation in the past, but which he hoped, through the publicity which Dr. Wheeler had given to the essential scientific character of the work, would not be the fashion in the future. Mr. Reginald Smith had raised a very important point, namely, that rather than that sites should be excavated unscientifically, it would be very much better that they should never be excavated at all. The evolving of a new technique for the archæological field worker was going to be carried even further in the future than it had been in the past. The digging over of sites haphazardly for objects of special interest for

museums was not archæology. Archæological field work gave to every fragment its position, importance and historical perspective. Excavation once done was irrevocable. Errors could not be made good. Evidence was lost for ever when once the site was unintelligibly disturbed. All the more reason, therefore, for this new technique of history by excavation. The past had its privileges, namely, that its record should be intelligently preserved; and the future had its rights, which should be protected against cupidity or idle curiosity. Care, knowledge, conscience and a complete technique were required to ensure both of these. He had often felt that there was a great problem in historical excavation which had not yet been faced, and that was the importance of the association of the objects which had been uncovered by the scientific archæologist. When those objects were dispersed and broken up they sometimes lost the cumulative effect of history which they gained under the intelligent and brilliant exposition of a trained archæologist like Dr. Wheeler.

Finally we had to ask ourselves the following question. When we looked at the national monuments, for work upon which such ridiculously inadequate sums were granted, we asked ourselves what did this love of the past mean; what was this craving for the knowledge of that which had gone? It appealed to the intellect as well as to the emotion; the vulgarly curious were not immune from its appeal. We recognised that it was the natural spirit of man to have that intelligent curiosity with regard to the past. He therefore said more strength to the skilled archæologist who would preserve the records adequately and who would state what they really meant without deluding us with pretty but misleading romances which merely led one astray.

He thought it had been learned from the lecture that the future of archæology was going to be much greater than its past. It was realised that history could safely be left in its hands, and that history undoubtedly would have in the future worthy servants to attend to its interests.

A vote of thanks having been carried unanimously, the meeting terminated.

NOTES ON BOOKS.

PARIS INTERNATIONAL EXHIBITION, 1925: REPORT ON THE INDUSTRIAL ARTS.
Department of overseas Trade. 7s. 6d.

The official report on the industrial arts, as represented in Paris in 1925, is a copiously illustrated book of articles by British experts, whose general remarks on their special subjects are not less interesting or valuable than the passages in which they describe what was actually to be seen at the show. A restatement of the principles of every art and craft appears to be necessary more than once in each generation. Old truths have to be driven home in the contemporary idiom, and, where something new under the sun is alleged to have been discovered, the relation of the discovery to the fundamental exigencies of commodity, firmness and delight have to be established by criticism without loss of time.

That something new had been discovered was the assumption made by the French authorities who organised the exhibition, the primary object of which was to give publicity to articles "of modern inspiration and real originality;" but, as Sir H. Llewellyn Smith explains in his introductory survey, it was allowed that "originality may be displayed as much in the development of existing art forms as

in the invention of the entirely new." In the case of printing, for instance, Mr. St. John Hornby points out that the essential qualities of the art have been unchanged since Gutenberg's day; knowledge and taste are expected of the modern typographer rather than originality.

The British exhibit of books, though creditable, did not do justice to the printers of this country. A certain unfortunate, but perhaps inevitable, unevenness was in fact manifest throughout the exhibition. On the one hand, Germany—the home of so many modern artistic tendencies—and the U.S.A. were altogether unrepresented; on the other hand France enjoyed a great advantage over other countries, since every encouragement (including large grants of money) was given to her nationals to enable them worthily to uphold the reputation of her industries.

The various contributors to the report provide the material on which to base an answer to the questions: What are the latest technical and aesthetic movements in such-and-such an industry, and what signs did the British exhibitors give of being as up-to-date as their competitors? The latest fashions in some cases, as Lalique's remarkable glass and certain brilliant French costumes, are to such an extent matters of luxury that they need not be considered with quite the same attention as developments, say, in a useful branch of the textile industry which are likely to affect large numbers of people intimately. And again, the signs of progressiveness given by British exhibitors were not always a satisfactory indication of the real state of affairs. Mr. Penrose is right to deplore the meagre place afforded to examples of Duncan Grant's contribution to the Arts of the Theatre, and the total absence of designs for scenery by William Nicholson and McKnight Kauffer.

With regard to textiles, Sir Frank Warner and Mr. Kendrick found that although there was much to admire in the British section, and although our exhibitors appeared thoroughly alive to the normal requirements of the world market, sound workmanship was not in many instances completed by a modern touch. But in textiles there is room for originality, and some of the smaller countries, as well as France, showed an enterprise in which the craftsmen of our own country (the heirs of William Morris!) were lacking. The popularity of batik work all over Europe is noted. Examples of this process, which was introduced by the Dutch from the East Indies in the early years of the present century, were shown by twelve countries, Great Britain not included. But where silk woven fabrics are concerned it is pleasant to read Mr. Kendrick's praise of Messrs. Warner and Sons three-pile velvet, which "had not a competitor in the Exhibition."

Perhaps one of the most interesting modern effects at the Exhibition was the *sggraffito* work of the forecourt in the Polish pavilion. This method of mural decoration is technically simple, and an economical one, and the design was in this case very good. Other remarkable achievements by nationals of the smaller countries were the table glass of the Orrefors works, Sweden, and the pottery of the principal Danish factories, the Royal Copenhagen and Messrs. Bing and Grøndahl.

It may be said in conclusion of this brief review that the conservatism of British industries in the past has been reasonable, and that there are signs at home—though these were not very evident in Paris—that manufacturers are anxious to get into touch with the artists whose co-operation is necessary, if solid, but rather dull goods are to be transformed to satisfy the urgent and rightful demands of modern taste.

P.B.

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FRIDAY, JULY 15th, 1927.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2.)

NOTICE.

PRESENTATION OF THE SOCIETY'S ALBERT MEDAL TO SIR ASTON WEBB.

The Council of the Royal Society of Arts attended at Clarence House on July 11th, when H.R.H. the Duke of Connaught, K.G., President of the Society, presented the Society's Albert Medal for 1927 to Sir Aston Webb, G.C.V.O., C.B., P.R.A., 1919-24, P.R.I.B.A., 1902-4, F.S.A., LL.D., "for distinguished services to architecture."

The members of the Council present were :—Lord Askwith, K.C.B., K.C., D.C.L., Sir Charles Bayley, G.C.I.E., K.C.S.I., Mr. P. M. Evans, M.A., LL.D., Sir Robert Hadfield, Bt., D.Sc., F.R.S., Sir Thomas Holland, K.C.S.I., K.C.I.E., D.Sc., F.R.S., Sir Herbert Jackson, K.B.E., F.R.S., Major Sir Humphrey Leggett, R.E., D.S.O., Sir Philip Magnus, Bt., Mr. Alan A. Campbell Swinton, F.R.S., Mr. Llewellyn B. Atkinson, M.I.E.E., Captain Sir Arthur Clarke, K.B.E., Rear-Admiral James de Courcy Hamilton, M.V.O., Mr. Carmichael Thomas, Professor John Millar Thomson, LL.D., F.R.S., Lieut.Col. Sir Arnold Wilson, K.C.I.E., C.S.I., C.M.G., D.S.O., with Mr. G. K. Menzies, Secretary, and Mr. W. Perry, Assistant-Secretary.

PROCEEDINGS OF THE SOCIETY.

ANNUAL GENERAL MEETING

The One Hundred and Seventy-third Annual General Meeting for the purpose of receiving the Report of the Council and the Financial Statement for 1926, for the revision of the Bye-Laws, and also for the election of Officers and new Fellows, was held in accordance with the Bye-Laws on Wednesday,

July 6th, at 4 p.m. SIR THOMAS H. HOLLAND, K.C.S.I., K.C.I.E., D.Sc., F.R.S., Chairman of the Council, in the Chair.

THE SECRETARY read the notice convening the meeting, and the Minutes of the last Annual General Meeting, held on June 30th, 1926.

The following candidates were proposed, balloted for and duly elected Fellows of the Society :—

Amies, Arthur Barton Pilgrim, L.D.S., Edinburgh.
 Armstrong, John James Victor, Liverpool.
 Banerjee, Sudhansu Mohan, M.A., B.L., Bally P.O., Bengal, India.
 Cameron, Barton H., Gordonsville, Virginia, U.S.A.
 Campbell, Roy, London.
 Chan Kang Swi, Malacca, Straits Settlements.
 Cheesman, Miss Edith, London.
 Christensen, Niels Anton, Cleveland, Ohio, U.S.A.
 Clark, J. Badger, London.
 Dolby, Major Sir George Alexander, J.P., London.
 Dury, Alan Buxton, A.R.I.B.A., London.
 Egloff, Dr. Gustav, Chicago, Illinois, U.S.A.
 Evans, Miss Jennie, Rugby.
 Fiedler, Svend G., London.
 Ford, Joseph Swain, Bombay, India.
 Gambrell, Horace William, Rugby.
 Garner, H. H., Pomona, California, U.S.A.
 Haque, Mohammad Abdul, London.
 Hardy, George F., Sc.D., B.S., New York City, U.S.A.
 Henderson-Gibson, George Leslie, Valparai, India.
 Jackson, H. Gardner, Buffalo, New York, U.S.A.
 Jennison, William Franklin, M.Eng., Toronto, Canada.
 Kaye, Leonard, Harrogate.
 Lockwood, Kemp, A.M.I.Mech.E., Liverpool
 Kuntz, William Jacob, York, Penna., U.S.A.
 Neilson, William Hardcastle, O.B.E., M.Inst.C.E., M.I.Mech.E.
 Pandit, A. S., Multan, India.
 Rahman, S. H., Delhi, India.
 Ramsbotham, Joshua Fielden, M.Inst.C.E., London.
 Rhodes, Sir Campbell, C.B.E., Henley-on-Thames.
 Ross, John Kenneth Murray, London.
 Shankar, Kunwar D., Fatehpur Sikri, Agra, India.
 Sutherland, N., Semarang, Java, Netherlands East Indies.
 Tapman, Jr., Samuel Fletcher, New York City, U.S.A.
 Viswanatham, M., Bezwada, India.
 von Eckermann, Harry, Ph.D., Sparreholm, Sweden.
 Wadsworth, Hilton, Leysin, Switzerland.
 Webb, Maurice E., D.S.O., M.C., F.R.I.B.A., London.
 Webster, William Reuben, Bridgeport, Connecticut, U.S.A.
 Whitaker, Harold Thomas, Paris, France.
 White, W. H., Melbourne, Australia.
 Winecoff, Miss Anna Thompson, B.A., Laramie, Wyoming, U.S.A.
 Wood, Frank, Leeds.

THE CHAIRMAN appointed Colonel de Villamil and Mr. A. C. Ross, C.B., M.A., scrutineers, and declared the ballot open.

THE SECRETARY then read the following :—

REPORT OF COUNCIL.

I.—ORDINARY MEETINGS.

In order to realise the international interest that may suddenly be developed in any commodity which happens to be the monopoly of any single power, it is only necessary to mention the word "Rubber." About two-thirds of the world's rubber supply comes from the British Empire, and American buyers now take some three-quarters of the world's supply. The sudden rise in prices in 1925 caused a good deal of feeling in the United States, and led to the suggestion of such reprisals as curtailing the cotton crop, on which the industry of Lancashire largely depends. From this it can easily be seen that the whole subject is one of great importance, and it was a worthy theme for the Chairman's inaugural address. In order to illustrate the problem, Sir Thomas Holland selected examples from each of the three classes of raw materials, animal, vegetable and mineral. Shell-lac was exported from India two years ago to the amount of £6·7 millions, of which America took £4·5 millions. During the last twelve years the price has varied enormously, from 60 shillings per cwt. in the early years of the war to 800 shillings in 1920, after which it dropped to about 180 shillings. Obviously this is an unsatisfactory state of things, as the producers never know what the future has in store for them. The position of jute, which has now become a raw material of international interest, was similarly considered, and finally the Chairman insisted on the necessity of making precise estimates of our resources in minerals, which, he urged, are essential for economic as well as military reasons. Of the many lessons to be drawn from the survey of the whole problem not the least important was summed up in these words: "The country that has a monopoly of some essential raw material has a duty to civilisation in making it reasonably accessible to foreign consumers; and the chief way in commerce to demonstrate a duty is to show that it pays."

The Trueman Wood Lecture this session was delivered by Dr. R. J. Tillyard, who chose for his subject, "The Progress of Economic Entomology (with special reference to Australia and New Zealand)." A number of instances were described in which the services of insects were enlisted to destroy pests inimical to man. Among the most remarkable of these is the case of the prickly pear. Introduced into Eastern Australia as a botanical curiosity, this plant spread at an amazing rate. Thirty million acres of land were put out of cultivation, and every year another million acres were added to the desert. Chemical methods of exterminating the plant were tried, but the cost was prohibitive. At last a concerted attempt was made to find an insect

that would prey on the prickly pear. The cochineal insect was tried, and met with some success, and now another, *Dactylopius Tomentosus*, is being distributed widely through the infected area, and is giving excellent results. In work of this kind, infinite care has to be exercised, as, unless the most thoughtful precautions are taken, there is always a danger that the insect which is introduced as a cure may become a greater pest than the thing which it is designed to exterminate. Dr. Tillyard described the methods taken to guard against dangers such as these, and his whole lecture was one more illustration of the sermon so often preached before the Society—the constant need for research; and once again he showed that the cost of research is infinitesimal when compared with the results to which it leads.

Mr. Thomas Brough opened his paper on "Artificial Silk" by a brief historical *résumé* of the earliest attempts to make the material, and then proceeded to give some account of the four processes now in use—Chardonnet, Cupra-ammonium, Cellulose acetate and Viscose. The last method was described in considerable detail, being the process with which the author was most familiar. The paper was illustrated with a fine exhibition of fabrics, which showed various ways in which artificial silk is used in the manufacture of fabrics. Thus, some of the exhibits were made entirely of artificial silk, some of artificial silk in conjunction with worsted, some of artificial silk in conjunction with cotton, and some of artificial silk in conjunction with natural silk. Each of these materials has its peculiar merits, while the extraordinary lustre and brilliant colouring that can be secured in artificial silk are well-known to everybody.

The Society has always been ready to encourage any movement tending towards the improvement of the relations between employers and employed, and it therefore welcomed Mr. Warre Bradley's paper, "Industrial Welfare in Practice," in which he described the system in operation in the great firm with which he is connected. In addition to the more usual features of these schemes, such as clubs, recreation grounds, etc., Mr. Warre Bradley's scheme provides pensions for superannuated workers, grants for long service, grants for widows of employees, and an attractive convalescent home in the Surrey hills available without any charge, not only for employees, but for their wives and children as well. It is a rather obvious criticism of such a scheme that only a wealthy firm could afford it; but, heavy though the expenditure must undoubtedly be, Mr. Warre Bradley contended that it pays the company over and over again, for they receive the most willing service from their men, who refuse to strike and are absolutely contented in their work.

A great deal of interest has been taken recently in the Constantinesco motor car, which by the abolition of the gear-box simplifies the driving to a remarkable degree. The principle was explained by Mr. George Constantinesco in his paper, "The Torque Converter." The system is applicable not only to motor cars, but to railway locomotives, marine engines, machine tools and many

other purposes. Very large claims are made as to the efficiency of the torque converter: the engine is comparatively small and inexpensive, and the amount of petrol consumed is also greatly reduced. There appears to be some doubt in the minds of certain critics as to the possibility of making the valves which replace the ratchets and pawls sufficiently strong to stand the wear and tear, which is very severe; but, as the Chairman pointed out, "the squeeze is taken by a number of rollers instead of one, and there is practically no loose motion or backlash. . . . Compared with gear wheels which transmit large power by very few teeth at a time, the valve ought to last well."

The Burgomaster of Antwerp undertook early last year to read a paper on "The Port of Antwerp." Unfortunately he was prevented by illness from fulfilling his promise, but his place was taken at short notice by the Rev. Père de Cleyn, Directeur de l'Institut de Commerce St. Ignace. Antwerp is a port of call for the ships of nearly two hundred lines, and besides these vessels she is visited by a very large number of tramp steamers. The bulk of the merchandise shipped there comes from the hinterland and is very varied in character. The port is extremely well equipped with facilities for carrying out repairs, with railways tracks serving the quays, docks and goods stations (extending to over 220 kilometers) and is particularly up to date in the matter of crane-power. This means that vessels can be loaded and unloaded at a very rapid rate, and, as a result of this, Antwerp is now one of the busiest ports on the Continent.

In dealing with "Some Aspects of the Chemical Industry," Mr. W. J. U. Woolcock reviewed the outstanding features of the industry and pointed out its general trend. Among the most striking developments of recent years have been the large-scale manufacture of such varying substances as nitrogen, artificial silk, alcohol for power, and many kinds of pharmaceutical products, including drugs, narcotics and anæsthetics. The growth of the chemical industry may be said to date from 1856 when Perkin made the first aniline dyestuff, and this led by various roads to its present enormous development. The war naturally stimulated production to an extraordinary degree, and when peace was declared there was a great excess of plant above what was necessary to meet the needs of the consuming trades. Mr. Woolcock indicated the means which were adopted to restore the balance between supply and demand, and he concluded by emphasising the ever-increasing need for research, for co-operation between all members of the industry, and for international co-operation between the industries in different countries.

"The Development of the Petroleum Industry in Persia" was the title of a paper by Sir John Cadman. Although the presence of oil in Persia was a matter of common knowledge from the earliest times, it was not until 1872 that Baron Julius de Reuter made the first attempt to solve the problem—an attempt that ended, like many others, in failure. The man to whom the Persian oil industry really owes its existence was William Knox D'Arcy,

who, having made a large fortune in the Australian goldfields, turned his attention in 1901 to oil in Persia. Sir John Cadman gave an account of his long fight, which, after threatening to engulf all his financial resources, resulted with dramatic suddenness in an overwhelming victory. To-day Persia stands fourth on the list of oil-producing countries, with an annual output of four-and-a-half million tons, and the Anglo-Persian Oil Company employs in Persia over 1,000 Europeans, 3,000 Indians, and about 25,000 Persians. A film of remarkable interest was exhibited showing the industry in all its stages and giving an admirable idea of the extent and the highly developed organisation of the work.

The introduction of the drop hammer twenty or thirty years ago led to the production of forgings in dies which had previously been hammered out on the anvil by a smith, and the first methods adopted under this system have recently undergone a remarkable development. They were described by Mr. F. W. Spencer in his paper, "British and American Practice in the Working of Hot and Cold Metals." Formerly no consideration was given to the importance of having the fibre of the metal in the most suitable position to resist the strains to which it is subjected in service, but now the utmost care is taken to ensure that the metal is so distributed in forging that its maximum strength is realised in use. With the aid of a large number of slides, Mr. Spencer explained the most up-to-date methods used both in this country and in America in the manufacture of such articles as motor and bicycle fittings, and he expressed the hope that his paper might lead to further research in connection with the flow of metal under pressure both at ordinary and high temperatures.

In the course of a comprehensive paper on "Chemistry and the Supply of Drugs," Mr. Norman Evers described nearly all the drugs that are now on the market and indicated the part played by the chemist in their preparation. He pointed out that this country is still very deficient in the supply of synthetic drugs. In Germany, for instance, this industry has been closely connected with the manufacture of dyes, but the British dyestuff industries have taken but little interest in drug manufacture. The variety of materials now used in pharmaceutical preparations is very great: in some firms there may be as many as a thousand different drugs, chemicals, etc., which have to be regularly examined, whilst the research department must be in close touch with the latest work in physiology and biochemistry.

In dealing with "The Romance of the Organic Chemical Industry," Dr. E. Frankland Armstrong selected the remarkable advances that have recently been made in the manufacture of the aliphatic alcohols and phthalic acid. By the processes now in common use cheap alcohol is available for the varnish, lacquer and artificial leather industries, while large quantities are used as antifreezing agents in the radiators of motor-cars. Phthalic acid, a few years ago, was little more than a scientific curiosity. It is now made easily and

at a low cost by the catalytic oxidation of naphthalene, and has become a raw material for some of the most striking syntheses in the dye industry. It is also used in the manufacture of lacquer and as the basis of an artificial resin of exceptional electrical properties. Enormous progress is being made by the chemical industries in the cheap production of large quantities of necessary materials; and the advances which have been achieved are the most eloquent plea for the need of more and ever more research.

The annual world consumption of electric lamps to-day is 600 millions, of which this country makes and uses about 30 millions. Ten years ago the output of ordinary lamps during the final stages of manufacture was at the rate of three per operator per hour. To-day the rate frequently touches 25 per operator per hour. An account of the huge development which has made this advance possible was given by Mr. C. C. Paterson in his paper, "Some Studies in the Manufacture of Electric Lamps and Thermionic Valves," in the course of which he explained a few of the many problems with which the electric lamp manufacturer has to deal. He must have a wide and deep knowledge both of chemistry and physics, and must understand the nature of such varying subjects as glass, filaments, wires, metals, gases and vacua. He must further possess a thorough understanding of such matters as the reactions of tungsten atoms and crystals to stress and temperature, and he is frequently faced with problems to which science has as yet given no answers. The paper was illustrated by a number of striking experiments and a fine show of lamps and valves.

The discovery of insulin by Banting and Best five years ago has led to a complete reformation in the treatment of diabetes, with the result that what used to be regarded as a fatal disease can now in most instances be kept under control. Mr. Francis H. Carr, in his paper, "Insulin and its Manufacture," described its action and quoted some remarkable figures to show the beneficial effects of the drug. Thus, out of 130 diabetic children treated with insulin, 120 were still living; while of 164 similar children who were not so treated, 152 were already dead. The story of the manufacture of insulin in this country is greatly to the credit of British firms. At first many people were of opinion that as American conditions were particularly suitable for it, and as one well-known American firm had already been engaged in the business for about a year, it would be as well to leave the whole matter in American hands; but several British firms refused to accept this point of view, with the result that they have caught up the American firms in respect of quality and amount of output, and further they have reduced the price to a level which eighteen months ago would have been considered quite out of the question.

Mr. Ulick Evans has for a good many years been studying the problems of corrosion, and he gave the Society the benefit of his researches upon one interesting portion of the subject in the paper which he read on "The Corrosion of Metals at Joints and Crevices." In view of the large financial losses,

and occasionally the serious accidents, due to corrosion, anything which throws a light on the problem must be of importance. The failure of the roof at Charing Cross Station some twenty years ago was a case in point, and another was the fate of the luxurious American yacht, the "Sea Call," in which, by an oversight, steel rivets were used, with the result that they corroded at once and at the end of the trial trip the boat was scrapped. Mr. Evans described a number of researches which he himself has conducted, throwing light on what takes place in different types of joints; and this led to an interesting discussion as to the nature of the solder most suitable for various purposes.

A great deal has been written and said in recent years about the necessity for smoke prevention. The case against smoke has been abundantly proved and the remedies are a matter of common knowledge; but the attractions of the open coal fire are so great that it still holds its own against gas and electric heating. Quite recently, however, developments have taken place which seem likely to make it possible for the citizen with a proper sense of his civic duties to enjoy a cheerful fire of smokeless fuel. Several grates have come into the market in which coke may be burnt as easily as coal. An account of these was given by Dr. E. W. Smith in his paper, "The Utilisation of Gas Coke," in the course of which he also described various forms of apparatus in which coke may be burnt for such purposes as the production of hot water for domestic use and for heating by hot water radiators. Apart from its domestic uses coke is being burnt in considerable quantities in industrial works bakers' ovens, fried fish shops, etc., and one of the most recent departures is its employment on coasting steamers.

The position of agriculture to-day causes much concern to those who are interested in it, and in most areas farmers are passing through a very difficult time. Not least of their difficulties is the supply of labour. The lure of the town continues to draw young manhood from the country, and the present rate of agricultural wages, which, according to many authorities, are as high as the industry justifies, is insufficient to retain the services of lads who desire to improve their conditions. These and similar matters were discussed by Mr. C. S. Orwin in his paper, "The Transition of Agriculture." He was of opinion that the existing state of affairs can hardly continue, and he anticipated that, if agriculture is to hold its own in this country, it will be necessary to develop large-scale production of two kinds: on arable farms, where the bulk of the work will be carried out by machinery, and on grass farms of the nature of ranches, where the labour will consist entirely of stockmen and shepherds.

It is often said that cinemas in this country are filled with foreign films because they are better than the British pictures. While it would be difficult to imagine anything worse than many of the foreign films that are shown, it is true that, for various causes, they have contrived to acquire the lion's share of our picture houses. The reasons for this were discussed by Colonel

Sir Arthur R. Holbrook, in his paper, "British Films." In view of the incalculable power for propaganda purposes which the film possesses, the matter has become serious, especially when one considers the effects that may be brought about in the less advanced outposts of the Empire. It is over two years since the Prime Minister stated his opinion that it is desirable on national grounds that the larger proportion of films exhibited within the Empire should be British, and the importance of the question was fully realised at the Imperial Conference last year. With a view to improving the state of affairs the Government recently introduced the Cinematograph Films Bill, the principal provisions of which were examined in some detail by Sir Arthur Holbrook.

Under the Fothergill Trust* the Council offered a prize of £100 for an essay on "Fire Waste (Loss of Property by Fire) and its Effects on the Economics of National Life in Great Britain." The prize was won by Mr. G. E. Keay, who on the invitation of the Council read his essay in a condensed form at an Ordinary Meeting in April. After emphasising the extent of the damage—both direct and indirect—caused to the country by fire, Mr. Keay dwelt at some length on various aspects of insurance, which led to a discussion of the work of the fire surveyor and of the steps that he can take to minimise the risks of fire. Interesting points were raised in connexion with the administration of fire brigades and salvage corps throughout the country, and a final word was said as to the desirability of instituting a proper system of public instruction in the principles of fire waste and fire risk.

It was only found possible to print the condensed form of the essay in the *Journal* but it is hoped that arrangements may be made to publish it elsewhere in full.

Unless the excavation of an historic site is carried out scientifically it is better not to carry it out at all. This appeared to be the principal lesson conveyed by Dr. R. E. Mortimer Wheeler's paper, "History by Excavation," and the reason is fairly obvious. In the course of time ancient sites become covered with earth, decayed vegetation, what not?—and in this accumulation lies buried much of the history of the site. It cannot be disturbed without disturbing and destroying historical or archaeological evidence. By careful removal of the accumulated strata in the cave of Altamira in northern Spain, and by study of what was removed, it was shown that about 15,000 B.C. there were artists whose work at its best, for delicacy and vividness of observation, has never been excelled. Other examples of the value of "stratification" were taken from the excavation of Roman sites in Britain, especially at Glastonbury, Carnarvon, Caerleon, and the Devil's Dyke, near Cambridge. The soil of this country bears beneath its surface much that may enable the trained mind to read the history of the past, and it is the duty of the public to safeguard these historic relics so far as in them lies.

* See page 854 below.

The last paper read at the Ordinary Meetings was entitled "Industrial Welfare in Great Britain and the United States." The author, Mr. Robert R. Hyde, emphasised the fact that industrial welfare work aims at removing at their source causes of unrest, bitterness and hardship, and seeks to restore under present-day conditions something of the personal relations between employer and employed which once existed. A number of opinions were quoted from important firms which all testified to the beneficial results of welfare schemes. A recent visit to the United States enabled Mr. Hyde to add some comments on industrial welfare work in that country. While he had been greatly impressed by some of the schemes that he had seen in operation there, he found it very difficult to make reasonably fair comparisons. American employers, owing to the scarcity of labour, were compelled, in order to retain their workmen, to maintain a very high standard in workshop amenities, and he thought that much of their welfare efforts were designed to stem the organisation of labour.

II.—INDIAN AND DOMINION AND COLONIES SECTIONS.

Eight meetings of the Indian Section, including that at which the Sir George Birdwood Memorial Lecture was delivered, and four meetings of the Dominions and Colonies Section were held during the Session.

In his paper on the report of the Indian Currency Commission, Sir James Brunyate, after first giving an outline of the pre-war currency system in India, which, he said, might fairly claim to have established the gold exchange standard as a practicable variety of gold standard, proceeded to subject the Commission's proposals to a detailed examination under the following headings :—(1) The internal stability of the rupee, (2) the external stability of the rupee, and (3) the correcting mechanism. While criticising the Commission's proposals under certain aspects, and emphasising the fact that in a country like India—where the psychological factor, the adherence to traditional methods, and the habit of cash transactions have so large an influence—the manner in which a new monetary system would work out was extremely difficult to gauge, Sir James summed up his final conclusion in the following words : " One cannot question that the new system will be of great advantage to India. . . . I can hardly think that the whole structure will need to be once more rebuilt as long as gold continues to be generally accepted as the standard of value."

The importance of town-planning is now very generally recognised and the account given by Mr. Bompas of the extremely bad conditions which have resulted from the lack of it in Calcutta, and of the measures recently taken by the Calcutta Improvement Trust to remedy those conditions as far as possible, was of peculiar interest. After referring to the outbreak of plague at Calcutta in 1896, which led to the appointment of a Medical Commission in 1896 and a Calcutta Building Commission in 1897, Mr. Bompas indicated in outline the scope of the Bengal Act of 1911, under which after long delays

the Calcutta Improvement Trust was established, and of the financial provisions which constituted the endowment of the Trust. He explained the special difficulties which have confronted the Trust owing to the extraordinarily high price of land in and around Calcutta, to the greatly increased cost of reconstruction work after the war, and to the boom and subsequent slump in land values; and described in detail some of the schemes actually carried out. The paper concluded with a summary of the amount and cost of the work accomplished up to date.

In his paper on "The Forecasting and Control of Cholera Epidemics in India," Sir Leonard Rogers, whose eminent services to India in the control and prevention of disease are well known, embodied the results of the researches bearing on the control of cholera epidemics, on which he had been working for a period of nearly two years. After adducing reasons for discarding the century-old theory that cholera spreads over India in epidemic waves from Bengal, Sir Leonard went on to shew by means of maps and charts, on which the results of an examination of over 70,000 data regarding climate and cholera incidence had been recorded, that a close relationship exists between cholera epidemics and the high absolute humidity of the atmosphere—which is essentially a measure of combined heat and moisture—and that deficient rainfall and pilgrimages are also most important factors in the spread of cholera. In conclusion, Sir Leonard emphasised the high protective value of anti-cholera vaccination, and presented a strong argument for controlling epidemics by administrative action, i.e., by making inoculation compulsory for all persons travelling to fairs and on pilgrimages when the meteorological conditions showed that outbreaks of cholera were likely to occur.

Some of the main tendencies in the course of international trade, especially with regard to price fluctuations and the relation between wholesale and retail prices in the post-war as compared with the pre-war period, were outlined by Mr. H. A. F. Lindsay in his paper on "World Tendencies reflected in India's Trade." Mr. Lindsay illustrated these general tendencies by charts, showing the price fluctuations, before and after the war, of Indian staple commodities, such as jute, cotton, shellac, tea, and wool, while other charts illustrated the relation existing between Calcutta prices and London stocks and the varying degrees in the fluctuation in prices of Indian raw products and of manufactured goods imported into India; the increase in the price of imported cotton piece goods, for example, being relatively much greater than the increase in the price obtained by the Indian producer for his raw cotton.

The Sir George Birdwood Memorial Lecture was delivered by Sir E. Denison Ross on "the Arabic History of Gujarat," the manuscript of which the lecturer discovered in 1901, 300 years after its composition, in the library of the Calcutta Madrasa, and has since edited for publication in the *Indian Record Series*. The history, which was written by a young Moslem of Indo-Persian descent, is divided into two parts, the first of which gives a detailed account of the

Moslem kings of Gujarat, while the second deals with the history of Muhammadan rule in other parts of India up to the end of the reign of Akbar. After giving an outline of the contents of the manuscript and an estimate of its historical value, the lecturer concluded his survey with an account of some autobiographical incidents which are scattered here and there throughout the narrative, and throw an interesting light on the character and somewhat eventful life of its author.

The developments which have taken place in recent years in the Indian iron and steel industry, the creation of which on a large scale was due to the genius and patriotism of the late Mr. Jamsetji Tata, are of such importance that Mr. Richard Mather's paper on "The Iron and Steel Industry in India" was one of exceptional interest. After enumerating in detail the known resources of India in the necessary raw materials, viz., iron ore, coal, fluxes, manganese ore, charcoal and refractory materials, the lecturer gave the most recent statistics of the Indian production of pig-iron and manufactured steel, of exports of pig-iron, of the internal consumption of steel, and of the steel imported into India from various countries. He then touched on the general conditions affecting the industry in India, and on the question of tariffs, and expressed the view that the increased production of steel would be largely balanced by an increased demand, that the importations of steel from Great Britain and the Continent are not likely to diminish to any great extent for the next few years, and that even in later years India is likely to remain an important market for certain kinds of steel.

In his paper on "The Tibetan Countryside," Sir Charles Bell gave an interesting first-hand picture of Tibet, which, like ancient Gaul, is usually divided into three parts—the Northern Plains, the Valley of the Tsang-po, and Eastern Tibet—and of the various types of its inhabitants—nobles, peasants, shepherds, traders, priests, nuns, beggars and robbers. The lecturer gave a variety of interesting details as to the daily life of the Tibetans and afforded many side-lights on their manners and customs.

Assam is a country of which the ordinary person knows very little, and Mr. Basil Allen, in his paper entitled "Assam," drew such a convincing picture of its extraordinary scenic and other attractions that all those who heard or read his paper will have made a mental note that Assam is a country worth visiting. Beginning with a short description of the physical characteristics of Assam—of which the dominant features are the great Brahmaputra River and the Himalayas in the background—Mr. Allen gave a short survey of the political history of Assam during the last 100 years, of its part in the Great War, and of such matters as revenue and excise, the opium question, forests, the tea industry—which has on the whole been strikingly successful, and has more than made good the losses suffered in the slump of 1920—public health (with special mention of the invaluable discoveries of Sir Leonard Rogers in connection with Kala Azar), communications, and the customs of the hill tribes.

The first of the papers read before the Dominions and Colonies Section was entitled, "The Importance of Rubber in Economic and Social Progress," by Sir Stanley Bois. Beginning with the discoveries of Hancock and Mackintosh early in the 19th century in regard to the application of rubber for waterproofing, and with the discovery of the vulcanisation process about the year 1840, the lecturer referred to the various developments in the use of rubber, *e.g.*, for bicycle and motor tyres, and for surgical and electrical purposes, which have had most important economic and social consequences, and to its possible future use on a large scale for other purposes, such as road-surfaces in towns. He also gave an outline of the growth of the rubber plantation industry—with its violent fluctuations of price levels—and emphasised the value of the Stevenson scheme in assisting to secure that stabilisation in price and production which in the long run is so much to the interest of both producers and consumers.

In his paper on "The Sugar Resources of the British Empire," Mr. Ben Morgan gave a resumé of the present position of the Empire in regard to sugar supplies. The figures which he quoted showed that while the Empire production of cane sugar was about the same in 1924-25 as in 1914-15, this production represented $34\frac{1}{2}$ per cent. of the total world production in the former year and only 25 per cent. in 1924-25, mainly owing to the great increase in the production of the United States and its dependencies. On the other hand, owing to the preference granted on Empire sugar, the Empire percentage of total sugar imports into Great Britain rose from $8\frac{1}{2}$ per cent. in 1914 to 21 per cent. in 1925. After referring to the advantage enjoyed by the sugar industries of foreign countries in being very highly organised and strongly protected in their home markets, the lecturer stressed the need for closer co-operation between all branches of the sugar industry throughout the Empire.

The appointment in 1923 by the Colonial Office of an Advisory Committee on Native Education in Tropical Africa has had the satisfactory result of focussing on this important subject the informed opinion and first-hand experience of missionaries and administrative officials who have been in the closest touch with it. Mr. J. H. Oldham's paper on "Recent tendencies in African Native Education" thus served the valuable purpose of providing a short statement of the problem as it appears to one who, by reason of his intimate knowledge of missionary work and of his membership of the Colonial Office Advisory Council, is well qualified to express an opinion. The leading note of the paper was that, whereas in the past the policy adopted in regard to native education followed the precedent laid down by Lord Macaulay in India, *viz.*, to base the education of the native on English or European culture, the modern view is that this policy was mistaken and that the native should be taught to have a high regard for his own language and culture, and as far as possible to base his future progress upon the best elements in his own tradition.

The lecturer concluded by expressing the hope that the partnership of the African Governments and the missions in native education, which had hitherto been working with remarkable success, would result in a still closer and more effective co-operation as the educational aim to be achieved came to be more clearly apprehended on both sides.

A paper on "Spanish Morocco," by Señor Don Tomas Baldasano, provided a fitting complement to one on French North Africa, which was read in the preceding session. After referring to the special geographical characteristics of Morocco, which have determined to a large extent its history, and to the close relations which have existed for centuries between Spain and Morocco, the lecturer proceeded to give an account of the considerable progress in mining and agricultural development, education and communications, which have been effected by the Spanish Government, particularly in recent years. The lecture was illustrated by a large number of photographs of buildings, mines, roads, railways, etc., which were projected on the screen by means of an epidiascope and bore witness to the material development already carried out in the Spanish zone.

III.—CANTOR LECTURES.

The first course of lectures under the Cantor Trust was delivered by Dr. L. C. Martin, his subject being "Recent Progress in Optics." There is now a vast range of applications of optical instruments in industry, science and ordinary life, and some idea of the high degree of perfection attainable may be gathered from the fact that surfaces can be made accurate to 0.00005 of a millimetre. The latest practice in the methods of polishing and grinding surfaces was explained, and the manufacture and testing of large astronomical reflectors were described. Considerable attention was given to the production of optical glass of various types, including developments in bi-focal spectacle lenses, photographic lenses, surveying instruments and range finders, and, recent advances in microscopy and dark-ground illumination; and, finally attention was drawn to the use of ultra-violet radiation in microscopy for research on cancer.

The second course on "Photo-elastic measurements of Stress Distribution" was given by Professor E. G. Coker. The lecturer began by explaining the fundamental principles of photo-elasticity and their application to the measurement of stress. By throwing a beam of polarised light through a transparent substance, such as a piece of celluloid, and then subjecting the substance to stress, he projected an image on the screen in which the colours varied in a remarkable way according to the amount of stress. By this means it is possible to measure stresses with extreme accuracy, and to give ocular demonstration of the precise spots in which it is greatest. The method is exceedingly valuable in solving engineering problems of stress distribution, and it throws a very clear light on such matters as the action of cutting tools, etc.

Mr. G. I. Finch gave the third course on "Some Industrial Applications of Electrothermics." After a general discussion of the principles of converting electrical energy into heat in ohmic and non-ohmic resistances, he described in detail various methods used in the fixation of nitrogen and allied industries. The application of electrothermics to metallurgy was dealt with in detail, and a demonstration was given of the use of the "death ray" in melting metals.

The last course was delivered by Mr. John W. T. Walsh on "The Measurement of Light." After a brief résumé of the history of the subject the lecturer discussed the principles of measurement and the value of the eye as a measuring instrument. A number of the photometers now commonly in use were explained and their action demonstrated experimentally. The question of the relative intensity of brightness from lights of different colours was dealt with, and the course concluded with a description of the photometry of stars, searchlights and other projectors.

IV.—HOWARD LECTURES.

Under the Howard Trust, Professor H. L. Callendar delivered a course of three lectures entitled, "Recent Experiments on the Properties of Steam at High Pressures." With the invention and development of the turbine many new problems were raised, while in quite recent years the high price of coal has given fresh importance to the question of economy in the utilisation of fuel. There are many difficulties in measuring with accuracy high pressures and temperatures. The various instruments used for these purposes were explained and illustrated, including modern electrical methods, throttling calorimeters, differential throttling calorimeters, etc. Methods of generating high-pressure steam for experimental purposes were discussed, and the continuous condenser method of measuring the total heat of steam at high pressure was fully described.

V.—DR. MANN LECTURES.

A course of two lectures on "English Railways" was delivered by Professor W. E. Dalby under the Dr. Mann Trust. The gradual development of our railways during the last eighty years was traced with especial reference to the following points: (1) capital expenditure, (2) receipts, (3) cost of working and (4) the development of the locomotive to meet the increasing demands of traffic. Attention was drawn to special problems of bridge design and recent researches in connection therewith, and a number of illustrations were given to demonstrate variations of rail load produced by the locomotive.

VI.—DR. MANN JUVENILE LECTURES.

Professor Charles R. Darling gave two Juvenile Lectures under the Dr. Mann Trust on "The Story of a Wireless Valve." He traced the origin of the wireless valve to Hauksbee's discovery that when mercury is shaken up

in an exhausted globe, bright flashes of light are emitted. Further study of electrical discharges in vacua led to the discovery of the electron, and the later discovery that electrons are given off by heated solids led to the invention of the thermionic valve by Professor Fleming. The use of the valve in transmitting sounds from a wireless station was fully explained, each stage in the process being demonstrated by numerous experiments.

VII.—ALBERT MEDAL.

The Albert Medal of the Society for the current year has been awarded by the Council, with the approval of the President, H.R.H. the Duke of Connaught, to Sir Aston Webb, G.C.V.O., C.B., P.R.A., 1919-24, P.R.I.B.A. 1902-4, F.S.A., LL.D., "for distinguished services to Architecture."

Amongst his works may be mentioned the new façade to Buckingham Palace and the architectural surroundings of the National Memorial to Queen Victoria; the Admiralty Arch, Charing Cross; the completion of the Victoria and Albert Museum; the Britannia Royal Naval College, Dartmouth; the Royal College of Science, Dublin; the Imperial College of Science and Technology, South Kensington, and many other public and private buildings. His appointment to the office of President of the Royal Academy was a recognition of Sir Aston Webb's great position in the profession of architecture.

VIII.—MEDALS FOR PAPERS.

Eleven medals have been awarded for the papers read before the Society during the current session—six for papers read at the Ordinary Meetings, four for those read in the Indian Section, and one for a paper read in the Dominions and Colonies Section.

The awards are as follows:—

Papers read at the Ordinary Meetings:—

Thomas Brough, J.P., Chief Designer, Messrs. Courtaulds, Ltd., "Artificial Silk."

Warre S. Bradley, F.C.I.S., Secretary, Messrs. Watney, Combe, Reid and Co., Ltd., "Industrial Welfare in Practice."

William J. U. Woolcock, C.B.E., General Manager, Association of British Chemical Manufacturers, "Some Aspects of the Chemical Industry."

Clifford Copland Paterson, O.B.E., M.I.E.E., F.Inst.P., General Electric Company's Research Laboratory, Wembley, "Some Studies in Connection with the Manufacture of Electric Lamps and Thermionic Valves."

Francis H. Carr, C.B.E., F.I.C., President of the Society of Chemical Industry, "Insulin and its Manufacture."

C. S. Orwin, M.A., Director, Institute of Research in Agricultural Economics, University of Oxford, "The Transition of Agriculture."

Papers read in the Indian Section.

Sir James B. Brunyate, K.C.S.I., C.I.E. "The Report of the Indian Currency Commission."

Cecil Henry Bompas, C.S.I., "The Calcutta Improvement Trust."

R. Mather, "The Iron and Steel Industry in India."

B. C. Allen, C.S.I., "Assam."

Paper read in the Dominions and Colonies Section :—

J. H. Oldham, Secretary of the International Missionary Council and Member of the Colonial Office Advisory Committee on Native Education in Tropical Africa, "Tendencies in African Native Education."

For many years it has been the practice that no medals should be awarded to members of the Council, or to readers of papers who have previously received medals from the Society. Acting on this rule the Council were precluded from considering the following papers.—

Colonel Sir Arthur R. Holbrook, K.B.E., M.P., "British Films."

Lieut.-Colonel Sir Leonard Rogers, C.I.E., M.D., F.R.S., I.M.S. (ret'd.), "The Forecasting and Control of Cholera Epidemics in India."

The Council desire, however, to express their high appreciation of these papers.

IX.—FUND FOR THE PRESERVATION OF ANCIENT COTTAGES.

As a result of the paper on "The Preservation of Ancient Cottages," read before the Society by Sir Frank Baines in May, 1926, the Council, in January last, called a conference "to consider the best means of preserving the ancient cottage architecture of this country."* They were fortunate in securing as Chairman the Prime Minister, whose warm interest in everything relating to the English countryside is generally known. Mr. Baldwin warmly commended the Society for taking action in the matter, and moved "the establishment of a substantial fund for application on the broadest national lines in furtherance of this movement." The resolution was supported by the Earl of Crawford and Balcarres, the Right Hon. J. H. Whitley, P.C., M.P. (Speaker of the House of Commons), and Sir Alfred Mond, and was unanimously passed by the meeting, to which over forty interested societies and public bodies sent representatives. Shortly after this an appeal by the Prime Minister, with a supporting note by Mr. Thomas Hardy, was issued as an illustrated pamphlet, and widely circulated.

The thanks of the Council are due to the Worshipful Company of Carpenters, their Master, Mr. H. Westbury Preston, who represented them at the Conference, and Mr. J. Hutton Freeman, their Clerk. The question had a special interest for this Company, as the cottages which the Society seeks to preserve were the work of the village carpenters. The Master intimated that his Company were anxious to assist the movement, and they gave a luncheon at the Carpenters' Hall in aid of the Fund, at which the Lord Mayor and Sheriffs attended. Appeals for help were made by the

*A full report of the Conference was published in the *Journal* of February 11th, 1927, pages 304-316.

Master, the Lord Mayor, Sir William Plender, Sir Arnold Wilson, Sir Howell J. Williams, Sir Banister Fletcher and Sir Frank Baines, as a result of which over £940 has been subscribed to the Fund.

The total amount received is now just over £4,500. In view of the very wide publicity given to the conference and the Prime Minister's appeal—for which the Council would like to take this opportunity of expressing their appreciation to the Press generally—it must be confessed that this result is disappointing. It is generally admitted that the cottages which the Society seeks to save are one of the most charming and beautiful features of England, and it was hoped that all those who take pleasure in visiting our old-world villages would be anxious to contribute towards their preservation.

The Society has received one particularly interesting gift in connection with this movement. Mrs. Greg, of Coles, Buntingford, Herts., has presented to them the cottage known as "Buttonsnap," West Mill Green, Herts., which was at one time the property of Charles Lamb, having been bequeathed to him by his godfather, "the most gentlemanly of oilmen."

X.—THOMAS GRAY MEMORIAL PRIZES.

Under the Thomas Gray Memorial Trust the Council offered a prize of £100 for an essay on the following subject :—

A description of a voyage, with special reference to the questions of stability, rolling and pitching of sea-going vessels, and, to the methods of determining the position of a ship approaching and making the land during thick weather.

[The writer should take into consideration the many modern aids to Navigation, and describe the appliances used and their practical effect. He should also describe the methods employed in a vessel fitted with the ordinary equipment which every ship should carry, and include notes on steering, either with the ordinary or with the gyro compass, or both. The whole essay should be based on the writer's personal experience.]

The last day for receiving entries was December 31st, 1926.

The Council appointed the following judges :—

Professor T. B. Abell, O.B.E., M.Eng., M.Inst.N.A., Professor of Naval Architecture, University of Liverpool.

Captain W. Ellery, Mercantile Marine Department, Board of Trade.

Captain A. H. Ryley, Trinity House.

Twenty-seven essays were submitted.

On the unanimous recommendation of the judges, the Council awarded the Prize of £100 to

Mr. Laurence H. Morrison, of Gravesend.

They further highly commended

Lieut.-Commander L. W. Murray, R.C.N., and

Mr. Oswald M. Watts, of New Cross.

The results were published in the *Journal* of April 22nd, 1927, page 519.

The Council also offered a prize of £50 to any person "who may bring to their notice a valuable improvement in the Science or Practice of Navigation proposed or invented by himself in the year 1926 or in the years 1921-5 inclusive."

The last day for receiving proofs of claim was December 31st, 1926.

The Council appointed the following judges :—

Rear-Admiral H. P. Douglas, C.M.G., Hydrographer to the Navy.

Captain W. Ellery, Mercantile Marine Department, Board of Trade.

Captain A. H. Ryley, Trinity House.

Thirteen inventions were submitted.

On the unanimous recommendation of the judges, the Council awarded the prize to Mr. H. B. Goodwin, M.A., F.R.A.S., formerly Examiner in Navigation and Nautical Astronomy under H.M. Board of Education, for various works in connexion with Azimuth Tables.

The Council have further offered the following prizes to the best students of Navigation in the schools mentioned below for the year 1926-7 :—

Three prizes of £10 each to the Nautical College, Pangbourne ; *Conway*, Birkenhead ; *Worcester*, Greenhithe.

Five prizes of £5 each to *Arethusa*, London ; *Warspile*, London ; *Indefatigable*, London ; Lancashire Sea Training School ; *Mercury*, Southampton.

It is believed that these prizes will exercise a beneficial influence in encouraging young students to devote their attention to the science and art of Navigation.

XI.—FOTHERGILL PRIZE.

It was stated in the last Annual Report* that under the Fothergill Trust, the Council, in May, 1925, offered a prize of £100 for an essay on " Fire Waste (Loss of Property by Fire) and its effects on the economics of National Life in Great Britain." The last date for receiving the essays was July 31st, 1926.

Thirty-four essays were submitted for the Prize.

The Council appointed the following to act as Judges :—Mr. A. R. Dyer, A.M.I.C.E., Chief Officer of the London Fire Brigade; Lieut-Colonel Charles J. Fox, Chief Officer of the London (Fire) Salvage Corps ; and Rear-Admiral James de C. Hamilton, M.V.O., late Chief Officer of the London Fire Brigade, and Member of the Council of the Royal Society of Arts.

On the unanimous recommendation of the Judges, the Council awarded the Fothergill Prize of £100 to Mr. G. E. Keay, of the Norwich Union Fire Insurance Society, Ltd., Birmingham.

They further highly commended the essay of Mr. Burdus Redford, of Newcastle-upon-Tyne, and commended the essay of Mr. Wm. A. Thomson, of the Norwich Union Fire Insurance Society, Ltd., Norwich.

The winning essay was read in a condensed form by the author at the Ordinary Meeting on April 27th. †

XII.—ANNUAL COMPETITION OF INDUSTRIAL DESIGNS.

The fourth Annual Competition of Industrial Designs will be held at the Imperial Institute in July, by kind permission of the Director.

This year the competition is being held in the following sections :—Architectural Decoration (where prizes amounting to over £150 are offered) ; Textiles (where prizes amounting to over £400 are offered) ; Furniture (where prizes amounting to £100 are offered) ; Book Production ; Pottery and Glass ; and Miscellaneous. In the last section a number of prizes up to the value of £50 each are offered by various firms for posters, designs for boxes, show-cases, etc.

It has been the aim of the Council and of the various committees appointed by them to carry out this competition, to ensure that any designs approved by them should bear evidence that the designers possess not only exceptional artistic ability, but also a sound and practical knowledge of the materials and processes of their trades. The committees consist mainly of representatives of important manufacturing and commercial firms, and the judges nominated by them will not be likely to overlook the question as to whether a design submitted is suitable or not for the materials for which it is intended.

After the awards have been made, it is intended to exhibit a number of selected designs at the Imperial Institute ; probably also exhibitions will be held at suitable centres outside London, where the designs will be brought to the notice of manufacturers likely to be specially interested in them.

As soon as the judges have completed their work, it is proposed to issue, as formerly, a full report on the Competition, which will be published in the *Journal*, and circulated widely among manufacturers and competitors.

The Council have opened a Bureau of Information at which are kept the names and addresses of those candidates at the Annual Competition of Industrial Design whose work has been accepted for exhibition and who desire to obtain *bona fide* employment as designers. Although no guarantee of employment can be given, the information is placed at the service of manufacturers in search of designers, and it is hoped that in this way the Bureau may be of real service in bringing manufacturers and designers into touch with one another.

The Council desire to take this opportunity of placing on record their grateful appreciation of the interest taken in the Competition by Her Majesty the Queen, who visited the exhibitions in 1924, 1925 and 1926, carefully inspected all the work, and on each occasion purchased a design. Her Majesty's gracious action has very greatly encouraged not only the Council and the various Sectional Committees, but also the competitors.

† See page 844 above.

XIII. EXAMINATIONS.

Last year, in response to a wide demand, the Council inaugurated a third series of examinations in July, in addition to those which have for many years been held at Easter and Whitsuntide. Over 14,000 entries were received for the new series, and it will now be held regularly. In addition to this, at the request of the London County Council, the Society agreed to conduct a special set of group examinations for L.C.C. Junior Commercial and Junior Technical Institutes, and a further series of examinations for group certificates for students at Day Schools has been established. It is not yet possible to give the number of entries for all these examinations, but a full report will, as usual, be published in the *Journal* at a later date.

The liberality of the Worshipful Company of Clothworkers has enabled the Council, as in past years, to offer the usual silver and bronze medals. These medals are greatly valued by the successful candidates, and they contribute not a little to maintain the high standard of the examinations.

XIV.—ORAL EXAMINATIONS IN MODERN LANGUAGES.

The Oral Examinations are still in progress in various parts of the country. Particulars will be given in the annual report on the Examinations.

XV.—NEW COUNCIL.

The Vice-Presidents retiring under the ordinary regulations are : Sir Edward Gait, Sir Robert Kindersley, Sir Philip Magnus, the Duke of Northumberland, Dr. J. Augustus Voelcker, and Sir Alfred Yarrow. In their places the Council recommend Sir Alan Garrett Anderson, Sir Alexander Gibb, Viscount Inchcape (none of whom have served on the Council in any capacity during the current year), Sir William H. Davison, Rear-Admiral James de C. Hamilton, and Professor J. M. Thomson.

The Ordinary Members of Council retiring are : Sir William Davison, Sir Archibald Denny, Rear-Admiral J. de C. Hamilton, and Professor J. M. Thomson. In their places the Council recommend the Rt. Hon. George N. Barnes, Sir William J. Pope, Col. the Master of Sempill, and Mr. J. Swinburne, none of whom have served on the Council in any capacity during the current year.

The Council also recommend the appointment of Sir Philip Magnus as a Treasurer in place of Lord Askwith, who is nominated as a Vice-President by H.R.H. the President.

XVI.—OBITUARY.

The Society has lost a number of distinguished Fellows during the last twelve months.

Viscount Bearsted was a Vice-President of the Society and a member of the

Council at the time of his death. He contributed £1,000 to the Building Fund, and in other ways proved himself a good friend of the Society.

Sir Alfred Seale Haslam had been a member of the Society for over forty years.

Sir James Wilson frequently spoke in discussions at the meetings of the Indian Section.

Mr. Byron Brenan took a very active part in the meetings of the Dominions and Colonies Section.

H.H. the Maharaja of Dhar was a Life Fellow of the Society.

Sir Charles Walston gave several courses of lectures before the Society.

Major-General Beresford Lovett was very often present at meetings of the Indian Section, which he continued to attend until shortly before his death at the age of 87.

Mr. G. Walter Knox for many years audited the Society's books, and acted as Examiner in Bookkeeping.

Mr. Edward Bell was a member of the firm of George Bell and Sons, who have published the *Journal* since the first issue in 1852.

Mr. George R. Bunker, one of our American Fellows, was among the first to introduce modern methods in the sugar-refining industry.

Dr. Arthur William Crossley was Director of the British Cotton Industry Research Association's Shirley Institute, at Didsbury.

Sir Charles Ruthen rendered valuable service to the country as Director of Housing at the Ministry of Health.

Sir Hiram Shaw Wilkinson had a long and distinguished career in the Far East, where his last office was as Chief Justice for H.M. Court for China and Corea.

Mr. George Robert Jebb was a member of the Society for 37 years.

Obituary notices of these and some other Fellows have appeared in the columns of the *Journal*.

XVII.—FINANCE.

The Financial Statement for 1925, published in accordance with Section 40 of the Society's By-laws in the *Journal* of July 1st, shows that the excess of income over expenditure for the year was £828 15s. 9d. It also gives a statement of the Society's investments and the trusts standing in its name.

XVIII.—THE SOCIETY'S HOUSE.

It will be remembered that in 1922 the Society succeeded in purchasing the freehold of their house, which was designed and built for them by the Brothers Adam a hundred and fifty years ago. The impending sale of the remainder of the Adelphi, of which the greater part will probably be destroyed, will add greatly to the interest of the Society's House, which is likely to become the sole monument of the Brothers on the site so closely associated with their name.

The sum required to purchase the freehold was £42,000, while legal expenses and necessary repairs and alterations amounted to a further £8,000. The subscription lists, which have appeared in the *Journal* from time to time, show that the sum so far subscribed is about £43,400. There is, therefore, still a deficit of some £6,600, and the Council will warmly welcome any assistance in reducing this amount.

XIX.—DECORATION OF THE REAR WALL.

The Council have accorded their warm thanks to Sir George Sutton, a Vice-President of the Society, who has generously borne the cost of decorating the rear wall of the Society's House facing the Strand. The work has been carried out from designs by Sir Aston Webb and Son. A description was given in the *Journal* of May 20th, illustrated by two photographs, one showing the former wall and the other the present decorated wall, illuminated by flood light. It is generally agreed that Sir George Sutton's gift has worthily completed a building which was recently described in the *Times* as "that lovely work."

THE CHAIRMAN, in moving the adoption of the report, said that one feature he would like to emphasize was the excellence of the summaries of the papers. He would also like to draw attention to the list of medals awarded for papers read during the session. He was afraid that the medals would not be appreciated at their full value if a number of papers up to medal standard had not to be excluded. There were instances, too, in which papers which had been regarded by the Selection Committee as deserving of the distinction of a medal had to be excluded on account of some other disqualification; e.g., Sir Arthur R. Holbrook, as being a member of the Council, and Sir Leonard Rogers, as having already received a medal on a previous occasion, were ineligible. The Council would like to convey their appreciation and thanks to the retiring members, who had been regular attendants and had been in every way helpful to them during the year. The Council were particularly sorry to lose Sir Edward Gait, Chairman of the Indian Section. He could only repeat what the report had already stated regarding the Council's appreciation of the generosity of Sir George Sutton in bearing the cost of decorating the rear wall.

SIR EDWARD GAIT, K.C.S.I., C.I.E., seconded the adoption of the report.

The report was unanimously adopted.

THE CHAIRMAN then moved that the Bye-Laws, as revised, be adopted. The Council had devoted several meetings during the past year to a survey

of the Bye-Laws, which had been altered from time to time, the most recent occasions being in 1910, 1914, 1920 and 1925. The result was that the Council felt it to be desirable that the Bye-Laws, having suffered from a certain amount of patching, should now be thoroughly consolidated so as to include all the changes which had been found desirable in the past and a few others the need for which had become apparent in recent years. For the re-drafting and re-arrangement of the Bye-Laws the Society was greatly indebted to the Honorary Solicitors, Messrs. Bristows, Cook and Carpmael, who had devoted a great deal of time and attention to the matter. The Chairman then drew attention to the various alterations proposed, the more important of which were the following :—

Section 4. The sum which may be kept on the Society's premises for petty cash expenses is raised from £30 to £100. This change is rendered necessary by the increase in the Society's business in recent years.

Section 15. This Section provides for the appointment and dismissal of the Secretary by the Council instead of by a vote of a General Meeting of the Society, and replaces Sections 22, 23 and 24 of the old Bye-Laws.

Section 42. In view of the permanent and important place which the meetings of the Indian and Dominions and Colonies Sections take in the Society's annual programme, it was thought desirable to make specific provision for these meetings and for the meetings of any other special Sections of the Society which may be formed in the future.

Section 47. This Section provides for the election of new members by the Council after their names have been exhibited on a board in the Rooms of the Society for a period of 10 days in place of the former procedure of election at Ordinary Meetings. The latter procedure had become unsuitable owing to the presence of visitors at Ordinary Meetings.

(Copies of the Bye-Laws, as amended, can now be obtained by Fellows on application to the Secretary.)

MR. R. À-ABABRELTON, in seconding the Chairman's motion for the adoption of the Bye-Laws, suggested that it would be desirable that the names of candidates for election as Fellows of the Society should be screened in the rooms of the Society, and that their names should be published in the *Journal*, so that they could be scrutinised by Fellows. He also suggested that it might be desirable that Fellows should have been informed beforehand as to the nature of the proposed alterations in the Bye-Laws.

THE CHAIRMAN stated that the names of members proposed for election would continue to be published in the *Journal*, as heretofore, and they would also be screened in the manner contemplated by Mr. à-Ababrelton.

The Bye-Laws, as amended, were unanimously adopted.

THE CHAIRMAN then proposed a cordial vote of thanks to Mr. G. K. Menzies (the Secretary), Mr. W. Perry (Assistant Secretary and Secretary of the Indian and Dominions and Colonies Sections), Mr. J. H. Buchanan (the Accountant and Examinations Officer), Mr. C. D. Cassidy (Librarian), Mr. H. J. Dack (Chief Clerk), and to the other officers of the Society for their services during the year.

The vote of thanks was carried unanimously.

THE SECRETARY, after returning thanks for this expression of confidence in himself and the other officers of the Society, greatly regretted to say that he had received bad news about the health of Sir Henry Trueman Wood. He was going to visit him shortly, and he suggested that the meeting might like to send a message of sympathy to Sir Henry Wood and of hope for his speedy recovery.

MR. À-ABABRELTON hoped that the Secretary would convey to Sir Henry Wood the warmest possible expression of their sympathy and appreciation of all the work that he had done for the Society.

The ballot having remained open for half-an-hour, and the scrutineers having reported, THE CHAIRMAN declared that the following had been elected to fill the several offices. (The names in italics are those of Fellows who have not, during the past year, filled the office to which they have been elected) :—

PRESIDENT.

H.R.H. The Duke of Connaught and Strathearn, K.G.

VICE-PRESIDENTS.

Sir Alan Garrett Anderson, K.B.E.

Sir Charles H. Armstrong.

*Lord Askwith, K.C.B., K.C., D.C.L.

Sir Charles Stuart Bayley, G.C.I.E., K.C.S.I.

Lord Bledisloe, P.C., K.B.E.

Sir John Cadman, K.C.M.G., D.Sc.

*Sir Dugald Clerk, K.B.E., D.Sc., F.R.S.

Sir William Henry Davison, K.B.E., D.L., M.P.

Sir Alexander Gibb, G.B.E., C.B.

Sir Robert Abbott Hadfield, Bt., D.Sc., F.R.S.

Rear-Admiral James de Courcy Hamilton, M.V.O.

Sir Thomas Holland, K.C.S.I., K.C.I.E., D.Sc., F.R.S.

Viscount Inchcape, G.C.S.I., G.C.M.G., K.C.I.E.

Sir Herbert Jackson, K.B.E., F.R.S.

Major Sir Humphrey Leggett, D.S.O., R.E.

Sir Charles C. McLeod, Bt.

Sir John O. Miller, K.C.S.I.

Hon. Sir Charles A. Parsons, O.M., K.C.B., LL.D., D.Sc., F.R.S.

Sir George Sutton, Bt.

- *Alan A. Campbell Swinton, F.R.S.
- Professor John Millar Thomson, I.L.D., F.R.S.*
- Sir Charles Wakefield, Bt., C.B.E.
- Sir Frank Warner, K.B.E.
- *Sir Henry Trueman Wood, M.A.

ORDINARY MEMBERS OF COUNCIL.

- Llewelyn B. Atkinson, M.I.E.E.
- Sir Frank Baines, C.V.O., C.B.E.
- Rt. Hon. George N. Barnes, C.H.*
- Captain Sir Arthur Clarke, K.B.E.
- Col. Sir Arthur Holbrook, K.B.E., M.P.
- Sir Reginald A. Mant, K.C.I.E., C.S.I.
- Sir William J. Pope, K.B.E., F.R.S.*
- Sir Richard Redmayne, K.C.B.
- Col. The Master of Sempill.*
- James Swinburne, F.R.S.*
- Carmichael Thomas.
- Lt.-Col. Sir Arnold T. Wilson, K.C.I.E., C.S.I., C.M.G., D.S.O.

TREASURERS.

- Peter MacIntyre Evans, M.A., I.L.D.
- Sir Philip Magnus, Bt.*

SECRETARY.

- George Kenneth Menzies, M.A.

THE CHAIRMAN proposed a vote of thanks to the scrutineers, which was carried unanimously.

SIR CHARLES S. BAYLEY, G.C.I.E., K.C.S.I., in proposing a vote of thanks to the Chairman, said they had all seen how ably he had carried through the business of the meeting, and this was typical of his conduct throughout the period of his Chairmanship of the Council. The Society was deeply indebted to him, and they only regretted that his term of office had come to an end.

CAPTAIN SIR ARTHUR CLARKE, K.B.E., seconded the motion, and the vote of thanks was carried unanimously.

THE CHAIRMAN, in acknowledging the vote of thanks, said that he had been ably backed up by the regular attendance at the Council meetings of his colleagues on the Council.

SCHEME OF THE WORSHIPFUL COMPANY OF GOLDSMITHS FOR IMPROVEMENT OF DESIGN IN SILVER-WORK.

The efforts recently made to draw attention to the artistic side of the manufacture of plate have attracted considerable notice. It has been evident from the wide-

- * Nominated by H.R.H. the President.

spread interest recently shown at Exhibitions, Meetings, and otherwise by the Press, the Trade and the public generally, that the idea of producing good silver work of modern design and craftsmanship to represent the artistic outlook of the present day is gaining support. There are many signs that the moment is opportune for a revival of the fine traditions of English silvercraft, and the Worshipful Company of Goldsmiths desire to invite the co-operation of all sections of the trade and of others interested in assisting such a revival.

The following steps are proposed :—

1. A competition on the lines indicated below for silver-work saleable at prices ranging from £1 to £50. Specimens selected by the Company's Judges will be purchased by the Company to the value of £500 (provided that, in the opinion of the Judges, sufficient good work is submitted), with a view to holding Exhibitions in various directions of representative modern work.

The Exhibitions will be open first to the Trade exclusively, and, subsequently, to the public; and if the competition is successful in attracting the work of original designers not already known, the opportunity will thus be afforded to the Trade for placing orders with them. An encouraging lead in this direction has already been given by one of the leading West End firms in an offer to purchase and display to the public individual work of merit produced under the Company's schemes. By such displays, good modern work should be prominently brought before the public, and a demand may gradually be created for types of work in the precious metals, in addition to purely utilitarian silver, which have often been regarded as unsaleable.

2. Meetings will be held at Goldsmith's Hall of representatives of Manufacturing and Retail Silversmiths, artist-craftsmen, members of Art Schools and others interested, to discuss, under pleasant conditions, questions affecting the Craft. Recent issues of Trade Journals show a desire to express opinions from various points of view, and it is hoped that discussion of the problems of modern silver production may show how the factories, the individual designers and craftsmen, the Art Schools, and the great distributing agencies, can combine to promote the common object, especially if beforehand representative speakers are nominated who are qualified to put clearly the different sides of the question.

It is suggested that the first meeting should be held in the Autumn.

3. Lectures, illustrated by lantern slides, will be given showing the evolution of silver wares in England and on the Continent from the earliest times to the present, and also on the problems of modern production.

One of the objects of these will be to bring salesmen and craftsmen into touch with one another, and the Company's Collection of Plate will be used for purposes of illustration.

4. Research into the subject of silver alloys or other methods of counteracting Tarnish.

The Judges will be Sir Edwin Lutyens, R.A., Mr. C. H. St John Hornby, Mr. Charles Aitken, Director of the Tate Gallery, Mr. B. J. Fletcher, Principal of the Birmingham Art School, Mr. F. H. Courthope and Mr. Arthur Duvall Bishop, with power to add to their number.

Full details of the competition, which is open to British subjects only, can be obtained on application to the Clerk of the Goldsmiths' Company, Goldsmiths' Hall, E.C.2. All entries must be sent in before the 15th October, 1927.

The Worshipful Company of Goldsmiths is not a trading company. The sole object of this scheme is an endeavour to stimulate and co-ordinate the efforts that are being made at the present time to produce work in the precious metals worthy of the past traditions of the craft, and to interest the public in such work.

NOTES ON BOOKS.

THE PRACTICAL BOOK OF DECORATIVE WALL-TREATMENTS. By Nancy McClelland.
London : J. B. Lippincott Company.

This is a practical book, as the title announces it to be. The text is systematic and matter of fact, the illustrations are well chosen and numerous—if anything, too numerous. It is the sort of book which helps those who can help themselves. Those with too little knowledge of the subject might be confused, and those with a good deal would not find the style inspiring. But there is much to be said for the bland neutrality of the authoress. The late philistinism in this country, where the decorative arts were concerned, was succeeded by a curiously un-English enthusiasm for modern design and devices, the idea being apparently, that something truly new had been discovered. The whole business was reminiscent of Tartarin's well-known ascent of the Rigi on foot.

The situation had its humour ; but on the other hand nothing is more sickening than the failure of the present to do justice to the past. Then again, to a great many people - who would not like to be confounded with the general public—the superb decoration of the renaissance and the eighteenth century suggests not so much fine art as the luxurious and privileged life of an arrogant ruling class. In a museum they may come upon a coquettish room in the Louis XV style : graceful wood panelling with damask inset ; elaborate stucco mouldings ; slender gilded chairs on a parquet floor—and at once they see a vision of Madame du Barri making inroads on the French exchequer.

Two of the most interesting photographs in the book are plates 404 and 405 ; a wall-painting by Veronese in a villa at Masèr, and a painted architectural decoration in a villa at Bagni a Ripoli. Miss McClelland rather naively says that “ artists now forget all about giving their work the quality of mural flatness.” What they did was deliberately to aim at creating in paint illusions of architectural elements. “ Raphael, Veronese, Titian and Tintoretto made use of painted architecture to complete their great decorations and bind them together. Not everyone who sees the Sistine Chapel for the first time realises that the ceiling is in reality only a flat surface, transformed into lofty vaulting by the perspective of a master hand.” Such realistic tricks should be marked by our contemporaries, who are out of sympathy with this kind of thing. Compare the very life-like gentleman in the half-open door in the villa at Masèr with the anatomically impossible clowns who appear in fresco on modern walls. We may prefer the flatness of the latter, but there is no denying the grandeur and brilliance of some of the simili-architecture with its human detail. In spite of difficulties it seems to comply with the rules of a wider æsthetic than is at present in vogue.

In one respect the “ Practical Book ” may not have an altogether healthy influence. Written, as it seems to be, chiefly for a rich American public, it rather suggests, if only by what is implied by some of the illustrations, that it is wise to reproduce old fashions as exactly as possible in modern houses. But about houses so treated there is generally something awkward and unhomelike, and it will probably be found that it is more satisfactory to exercise an eclectic taste, when furnishing, than to display mere antiquarian punctilio.

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All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2.)

NOTICES.

COUNCIL.

A meeting of the Council was held on Monday, July 11th. Present :— Sir Thomas Holland, K.C.S.I., K.C.I.E., D.Sc., F.R.S., in the Chair; Sir Charles H. Armstrong; Lord Askwith, K.C.B., K.C., D.C.L.; Sir Frank Baines, C.V.O., C.B.E.; Captain Sir Arthur Clarke, K.B.E.; Sir William Henry Davison, K.B.E., D.L., M.P.; Major Sir Humphrey Leggett, R.E., D.S.O.; Mr. Alan A. Campbell Swinton, F.R.S.; Mr. Carmichael Thomas; Dr. J. Augustus Voelcker, M.A., Ph.D.; Sir Frank Warner, K.B.E.; and Rear-Admiral James de Courcy Hamilton, M.V.O., with Mr. G. K. Menzies, M.A. (Secretary) and Mr. W. Perry, B.A. (Assistant Secretary).

Sir Philip Magnus was unanimously elected Chairman of the Council for the year 1927-28.

A scheme of prizes offered under the Thomas Gray Memorial Trust was approved. Particulars of these prizes will be published in the *Journal* and elsewhere shortly.

Regulations for a Staff Superannuation Scheme were provisionally approved.

The arrangements for judging the entries submitted in the Competition of Industrial Designs were reported.

The various standing committees of the Council were re-appointed.

Papers and courses of lectures for Session 1927-28 were considered.

On the motion of Lord Askwith a vote of thanks was unanimously accorded to Sir Thomas Holland for the services he had rendered to the Society by acting as Chairman of the Council for the years 1925-7.

Other formal and financial business was transacted.

DOMINIONS AND COLONIES SECTION.

A meeting of the Dominions and Colonies Section Committee was held on Monday, July 11th, to consider the arrangements for meetings of the Section during the forthcoming session. The following were present :—Major Sir Humphrey Leggett, D.S.O., R.E., Chairman of the Committee ; the Hon. Sir John Cockburn, K.C.M.G. ; Rear-Admiral James de Courcy Hamilton, M.V.O. ; Sir Thomas H. Holland, K.C.S.I., K.C.I.E., D.Sc., F.R.S. ; Sir Charles Metcalfe, Bt. ; Sir Francis J. Newton, K.C.M.G., C.V.O. ; and Mr. Carmichael Thomas, with Mr. G. K. Menzies, M.A., Secretary of the Society, and Mr. W. Perry, B.A., Secretary of the Section.

COMPETITION OF INDUSTRIAL DESIGNS,

The work submitted at the Annual Competition of Industrial Designs for Prizes and Scholarships offered by the Society and well-known manufacturers was received at the Imperial Institute, by kind permission of the Board of Governors, at the end of June. The judges in the various Sections are approaching the conclusion of the work of allocating the awards, and a selection of the designs received will be exhibited in the Indian Pavilion of the Imperial Institute, South Kensington, from the 30th of July to the 31st of August next, every week-day from 10 a.m. to 5 p.m. (Sundays 2.30 to 6 p.m.).

The Exhibition is open free of charge ; no tickets are required. It will include Designs in Architectural Decoration (Wrought Iron Gates for a City Company, Entrance Hall for a Block of Flats, Topographical Drawings, etc.), Textiles, Furniture, Printing and Book-Production, China, Earthenware and Glass, as well as Designs for Posters, Showcards, Lay-outs, Cartons and Price-Lists.

A Bureau of Information has been established at the Royal Society of Arts in connexion with the competition, for the registration of the names and addresses of exhibitors who desire to obtain employment as designers. These lists are at the service of manufacturers in search of designers.

A report on the competition, including full lists of awards, will be published in the *Journal* at an early date.

REPRINT OF HOWARD LECTURES.

The Howard Lectures on "Recent Experiments on the Properties of Steam at High Pressures," by Professor H. L. Callendar, C.B.E., LL.D., F.R.S., have been reprinted from the *Journal* in pamphlet form. The reprint (price 2s.) can be obtained from the Secretary, Royal Society of Arts, John Street, Adelphi, W.C.2.

A full list of lectures which have been published separately and are still on sale can also be obtained on application.

PROCEEDINGS OF THE SOCIETY.

TWENTY-FIRST ORDINARY MEETING.

WEDNESDAY, MAY 18TH, 1927.

SIR ROBERT A. HADFIELD, Bt., D.Sc., F.R.S., in the Chair.

The following paper was read :—

INDUSTRIAL WELFARE IN GREAT BRITAIN AND THE UNITED STATES.

By ROBERT R. HYDE,

Director of the Industrial Welfare Society.

In order to find a suitable introduction to the lecture this evening I searched my dictionary for a definition of the word "welfare"—a word which, during the days of its popular usage, connotes many activities. Unfortunately, one of the examples given of the use of its derivatives was, "There was a certain rich man which *fared* sumptuously every day," so I forsook my philological study and decided to fall back upon a very prosaic but safer definition. When we speak of industrial welfare we refer to a field of activity within the individual factory, mill or yard, which concerns matters of health, relationship, co-operation, education and training, social and recreational schemes, thrift, and accident prevention work. The field is fairly comprehensive, but questions of wages, hours, and the conditions of employment are not involved, since these matters are already dealt with by other organisations, and, as a rule, collectively.

But before treating the subject in detail it may be wise to sketch in the background in which this modern movement is taking a place, for unless our sense of perspective is correct, we are apt, in considering any industrial question, especially at the present time, to be swayed by pessimism. A few days ago a visitor from China was seeking information about the industrial welfare movement in this country. He stated that in some of the industrial centres in that vast continent conditions were almost identical with the conditions which prevailed in this country just a hundred years ago. Men and women were leaving their cottage crafts for the factory, and the employers wished to have the advantage of British experience lest they should repeat the errors which marred the early stages of our industrial development.

The introduction of mechanical power for the purposes of production, and the growth of the productive unit, were followed by a period of exploitation which, in this more enlightened age, almost passes belief. Let me read to you from a little pamphlet discovered a few days ago in an old desk in my office. It is entitled *The British Labourer's Protector, and Factory Child's Friend*, and

it was published in 1832, a date still within living memory. Richard Oastler had been reproved by a clergyman for having stated that the condition of the workers in the mills in Bradford was "more horrid than the Hellish System of Colonial Slavery," and in this pamphlet he takes up the matter in his forthright and forceful manner :—

"Let then these questions be fairly answered. Is the juvenile slave population of our West India Islands required to work, at the will of their masters, from 12 to 18 hours a day? No. Are they in thousands of instances obliged, in addition to this, to walk from one to three miles to their work in all seasons of the year, and in all weathers, frequently drenched with wet and starved with frost and snow? No. Besides all this, are they obliged to eat and weep and work, and work and weep and eat, in many cases having no time whatever allowed for meals, and in all cases, save two, in your own town, only 30 minutes per day for eating, playing, and learning? No. Is it a common case in the West Indies for the slave parents to call up and wake out of sound sleep, at four or five in the morning, little slave children from six to fourteen years of age, and send, or carry, or drive them to the mill, and after remaining all day idle themselves, "because no man will hire them," at eight, nine, ten, or eleven at night, nay sometimes later, to fetch them back, the children very often being so tired that they cannot walk? No.

Can you in the West Indies find many instances of little slave children who, in addition to these sufferings, can exhibit on their backs, or breasts, or heads, or faces, or arms, or legs, the marks of torture, inflicted by straps, or whips, or billy rollers, or hammers, or fists, or feet with heavy clogs on? No. Are there many instances in the West Indies of young slaves at the age of fourteen to seventeen who are absolutely worked and beaten till they can work no more—their backs and legs and arms distorted, and themselves, after devoting all their strength in the service of a cruel master, consigned to penury and want, compelled to subsist on Charity, or become the inhabitants of the Poor House? No. Are there many instances in the West Indies of the slave parents following their slave children to the grave, and knowing as they slowly move behind their corpses that they are laid there, the early victims of labour, and oppression, and cruelty, like that described above? No.

This deplorable age led, as we know, to vigorous protests; to the growth of Trade Unionism, factory legislation, and to the stirring of the public conscience. The period was one of change, of great development, not the least of which was in the mentality of the workers. Educational facilities, the Press, the extension of the means of transport, the granting of the political franchise, and, later, such influences as the film and wireless, have all served to quicken the intellect, and men and women are to-day wondering why there should be so great a contradiction between their political freedom and their economic dependence. In the past the worker was prepared to accept things as he found them: to-day he is challenging the very foundations of the established order.

Moreover, it is sometimes forgotten that amongst those whose minds are not continuously and actively engaged memories are long, and the old distresses and injustices which disturbed the last generation are still fresh and vivid. The old conditions under which work was carried on no longer obtain, but

bitterness has eaten into their thoughts. We have watched, too, in recent years the growth of class consciousness and class distinction, and there is little doubt that this is due, to some considerable extent, to the development of the Joint Stock Company, with its absentee ownership. The mere fact that one person is an employer and another an employee does not of itself produce a feeling of class distinction. A common interest in the common task unites and does not divide people. So long as the employer is primarily interested in some particular form of production or distribution, his contact with his workpeople does not produce a feeling of class distinction. When a generation arose that lacked his constructive interest in the job but cared more for consumption than production, then was produced a feeling of class distinction and class consciousness; interest was in the things that money would buy rather than in the work that is the source of the money.

This, in general, is the background of the Industrial Welfare movement which has been growing up side by side with the changes and developments to which I have referred. Industry has never been without noteworthy examples of welfare work, and pioneers have always played their part, although in their own age their work was often unrecognised. An interesting account of one welfare scheme appeared in the *Quarterly Review* in 1852. The directors of a London firm reported that in the past they had looked upon mechanics as no better than live machinery, and the Managing Director thought it possible "without loss or hurt to the business" to humanise those whom he called "the hands." An account is given of the various activities started, and the report ends with the words, "I trust that our factory will be different from one in which the giving and taking of wages is the only connection between the proprietors and their people."

Various outstanding examples of welfare work were to be found in this country in pre-war days, but during the War a great impetus was given to the movement by the setting up of a Welfare Department by the Minister of Munitions. Hundreds of thousands of workers were pouring into the National factories and controlled establishments, with the result that a number of problems connected with housing, transport, health, and discipline arose in a very acute form. Mr. Seebohm Rowntree, who had had considerable experience in dealing with all these questions in his factory at York, was given the control of this Department, and very useful work was accomplished in advising and assisting employers in starting welfare schemes. Towards the end of the war, a number of well-known employers came to the conclusion that this work was worth continuing on a voluntary basis and that its direction should be controlled and guided by industry rather than by a State Department, with the result that the Industrial Welfare Society was formed. One of its functions is to encourage the extension of welfare work, but its other main purpose is to serve as a clearing-house for information on every branch of welfare work. It has given direction to the aspirations and aims of the heads of a large

number of industrial and commercial firms who had the good-will, but lacked the experience and knowledge of method to give it practical and adequate expression.

The main appeal of the Society is that in every firm there should be a person—either a director, or a member of the staff, or a definitely-appointed welfare worker—whose duty it is to deal with a number of matters which closely concern the health, comfort, happiness and efficiency of the workers. He should regard industry from the human end, but lest this should appear to be fanciful, perhaps it would be well to add that in recent years active steps have been taken to promote this work in India, Italy, South Africa, Australia, China and Holland. From these countries we have been asked to give assistance in dealing with industrial conditions and relationship, so that many of the errors into which we have drifted may be prevented in those lands.

What are the human problems of Industry? I will endeavour to deal with them in as practical a way as possible.

It is sometimes urged by the workers that under the modern system by which industry is controlled they feel they are but pawns in a game—that they have no voice, no responsibility, no control in affairs which affect them closely in their daily toil. The claim is not that they may be allowed to interfere with management, but that they may take a real share in matters which are their intimate concern. Many progressive firms to-day are meeting this legitimate desire by forming Works Councils and Committees, and wherever there is enthusiasm on the part of the directors, backed by a representative Committee, which meets in an informal, friendly atmosphere, extremely useful work has been accomplished. The encouragement of suggestions from the workers; accident prevention work; the publication of a works magazine; social and recreational work; benevolent funds, all provide opportunities for bringing people together on a common ground. The very fact that personal contacts are made in this way does much to break down misunderstandings and suspicion. After all, the function of a Board of Directors is to interpret, as accurately as possible, controlling circumstances, and, since brain is not limited to any class or vocation, it is not contrary to reason, or expediency, to suggest that the staff and manual workers should have an opportunity of contributing to the well-being of the enterprise.

Much is being heard to-day of the domination of the machine, and outcry is often raised against the monotony of modern methods of production. The whole subject is very complicated and demands careful thought and study rather than rhetoric. Undoubtedly, there are many unhappy misfits in industry at the present time, but much can be done to avoid the unhappiness of uncongenial toil by making careful selection of the workers, especially where juveniles are concerned. Again, one finds a growing habit of giving the workers an opportunity of changing their occupation, but on the whole, so far as I have been able to discover, there is unwillingness on the part of the workers to forsake

the task they are engaged upon for an unfamiliar job. Much, too, is being done to alleviate monotony and fatigue by the introduction of a rest pause in the middle of the shift, and, undoubtedly, much attention will be devoted to this question in the immediate future. The provision of other interests associated with the place of work, such as recreational and social activities, also tends to remove the feeling of drudgery. There are many cases, too, where workers engaged on some uninteresting repetition job, are allowed to see the finished article, so that their interest in the particular part, in the making of which they are engaged, may be increased. Thus, in one firm, men who are engaged in repetition work connected with the manufacture of coal cutters are enabled from time to time to visit a mine where they can see the complete machine in actual operation. I have found, too, that such a simple thing as the giving of a word of praise for work well done tends to create, not only greater happiness in work, but increased zeal and efficiency also.

Another enormous factor in this field of human relations is that of health. From time to time the country is staggered at the loss of time resulting from labour disputes. But this loss, appalling as it is, is a mere fraction of the time lost to industry and to the community through sickness, much of which is preventable. The following figures will serve to indicate the serious nature of this problem. The weeks lost in Great Britain as a result of sickness amongst insured persons (and these figures do not include the first three days of illness) were, in recent years, as follows :—

1922	...	...	22,275,000
1923	...	...	23,050,000
1924	...	...	26,045,000

The weeks lost through Trade disputes at works actually involved in the disputes were as follows :—

1922	...	...	3,300,000
1923	...	...	1,800,000
1924	...	...	1,400,000

Much can be done by individual employers to obviate this suffering and loss. The provision of a canteen, where local conditions render it advisable, can contribute very effectively to the well-being of all concerned ; the adequate provision and maintenance of a first-aid and ambulance service, and the setting-up of medical and dental services, may involve an initial outlay of money which to many might act as a deterrent, but the cost is insignificant compared with the mutual advantages which follow. In the reduction of suffering, in the minimizing of trouble involved in training new workers, and in the lowering of compensation claims, there is no doubt that all these matters can exercise a very beneficial effect. The maintenance of working conditions, *i.e.*, heating, lighting, ventilation, sanitation, at a high standard, is another matter which at the present time is demanding the careful consideration it deserves.

Again, much is heard to-day of the insecurity of the worker, but steps may be taken to remove this feeling. By giving long notice, wherever practicable, when a cutting down of the staff is inevitable; the centralising of employment, so that the anomaly of one department dismissing while another is engaging may be obviated, and the inauguration of Pensions and Benevolent Funds are all means of minimising the haunting dread of sickness, unemployment, or old age. Sometimes we hear, too, that in these modern days of large-scale enterprise there is a lack of incentive in so far as the rank and file of workers are concerned. To provide this incentive is an exceedingly difficult question, and although many efforts are being made, the results are not yet altogether satisfactory. Some pin their faith to piece-rates and bonuses, and the matter is being discussed very carefully at the present time between groups of employers and workpeople. Others look to profit-sharing and stock-holding as a means of achieving the end, but the results to date appear to suggest that if an employer introduces a scheme of profit-sharing, with the object of stimulating his workpeople to increased zeal and work and maintaining the stimulus for a long period of years, he is not unlikely to be disappointed. At the same time, it is a hopeful sign of progress that thought is being directed to the amelioration of this and other difficulties which have no little bearing upon the whole question of industrial stability and peace.

Some months ago an enquiry was made regarding the effect of welfare work upon productive enterprise, and, as a result of evidence collected from upwards of 400 firms, the four following conclusions were strongly supported. Under the respective headings, I will read brief extracts from letters received from the firms involved :—

A. *That industrial welfare work is increasing both in volume and scope, and is regarded by progressive employers as an integral part of management.*

“We believe that by arranging that the applicant for employment is seen both by the Welfare Supervisor and the foreman, each of whom is looking from a different point of view, we are enabled to choose the type of worker best fitted, while the man knows that his case is carefully considered. We believe our labour turnover to be as low as it is possible.”

“One of the most important forms of welfare work, frequently overlooked, is sympathetic management. The employees feel that they cannot be dismissed until their case has been thoroughly investigated.”

“The need for such a department as an aid to management has been increasingly apparent.”

“We regard welfare work as an indispensable part of good management.”

B. *That it has a beneficial effect both directly and indirectly upon productive capacity and efficiency.*

Selection and training.

"Its result upon apprentices has been excellent."

"Welfare work has resulted in a high type of worker as regards cleanliness, intelligence and efficiency."

Relationship.

"There is a marked tendency to discuss matters, and in practically every instance an amicable settlement has been arrived at."

"Loyalty has improved."

"The absence of disputes to any appreciable degree provides evidence that the increased welfare work carried on in this factory gives an improved relationship between the management and the employee."

"The works committee no doubt has been of beneficial effect, acting as a safety valve for any grievances that may arise from time to time."

Labour turnover.

"During the slump many of our employees remained with us when they might have obtained full time elsewhere ; they remained because of the social amenities."

"There is a decreasing labour turnover which is very noticeable."

"Our welfare scheme has had an undoubted influence in preventing high labour turnover."

"There is a marked decrease in labour turnover."

"Our labour turnover is less because everyone from the management down is taught to regard it as a failure if a dismissal becomes necessary."

Health.

"Our compensation cases have decreased from 4.16 per cent. to roughly 1 per cent. in 8 years."

"Health has improved ; most marked in cases of sepsis. We hardly ever get the serious cases which were numerous before the medical service started."

"There is a definite improvement in health ; sick rates have been reduced in 3 years from 1.1 week per head per annum to .8 week per head. This is definitely due to improved methods of selection and the activities of the welfare department."

Efficiency.

"Operatives take an interest in time-saving and co-operative activities."

"We consider the tendency towards efficiency is intensified by welfare work, but we are unable to give any striking illustrations."

"There is a better spirit and more satisfied and contented atmosphere. Workers are proud to compare their conditions with other factories in the town. (In this particular firm all workers must be members of T.U.)"

C. *That although its value cannot be valued in terms of cash it results in improved relationship, effectiveness, health and interest.*

"We are convinced that welfare work pays, but we consider it unfortunate if balance of profit and loss had to be struck and the question considered only from this point of view."

"We have never attempted to correlate the spirit (i.e. created by welfare work) with matters of profit and loss, and think it would be unfortunate to try to do so."

"Tangible results are difficult to specify, but we are convinced that these are satisfactory and ample reward for any trouble or expense involved."

"We consider our scheme a fine investment."

D. *That its further development upon a voluntary and mutual basis would undoubtedly benefit British enterprise.*

Much has been done during the last ten years, quietly and effectively, along the lines I have indicated this evening, but much remains to be done. For example, only two days ago, the Home Secretary issued a warning that if employers did not undertake, voluntarily, Accident Prevention work, he would be forced to consider the compulsory appointment of a competent Safety Supervisor in certain classes of factories. Should this threatened Order ever become effective it will mean that progressive firms who have adopted every means of co-operation between themselves and their workers will find themselves hedged about with all sorts of vexatious regulations, necessitated, as the Home Secretary states, by the absence of signs on the part of employers generally to grapple with this question. In this connection it is interesting to recall that at the present time the Joint Industrial Councils are seeking power to make majority decisions binding upon an industry, since they feel that backward employers should not be allowed to hinder progress by refusing to adopt some progressive policy or standard which has been set.

by the progressive employers in that industry. The challenge is often made that "employers never take steps to improve relationship or working conditions unless, or until, they are compelled to do so." The document so recently issued by the Home Secretary, with very evident reluctance, certainly gives colour to this contention, and it would be a thousand pities if a movement fraught with such good and such endless possibilities should be endangered by the negligent or indifferent employer.

A few months ago I had an opportunity of visiting America and of seeing something of the welfare work in that country. Comparison, however, is extremely difficult, because of the different circumstances prevailing over there. Their vast, undeveloped home market has created an almost unlimited demand for commodities, and this, plus restrictive tariffs and recent immigration laws, has served to make an abundance of work and, on the other hand, a shortage of labour. America to-day is experiencing an era of prosperity unknown in the history of the world, and, superficially at any rate, the description of that country as "the workers' paradise" is not an exaggeration. The climate, too, must have a wonderful effect both mentally and physically upon the inhabitants, and I could not help feeling that the willingness to take risks, to adventure, was more commonly met with than in Great Britain. The shortage of labour has the effect of removing from the mind of the workers the feeling that the more one man does, the less there is for his fellow-men to do. Labour-aiding machinery is welcomed, and although its introduction may displace some workers, yet this is not regarded as a hardship, for in all probability another, and a better, job awaits the displaced man. There appears, too, to be an absence of hostility to "capitalism." Every man is a potential master, and the tradition of what is familiarly known as "the family deadwood" method of promotion is there almost unknown. The wider distribution of wealth, the accumulation of individual savings, stock-holding, insurance, and, to some extent, instalment purchase, have all had their effect in abolishing antipathy between what is loosely called "Capital and Labour." The whole background there is quite unlike the old traditional background in this country, with its prejudices, classes and customs. In many of the great works visited I was very much impressed with the very high standard of the medical and dental services, cafeterias, methods of centralising employment, and in such firms this work was as good as, if not better than, anything we can show in Great Britain, but in making comparison it must be remembered that labour is scarce, therefore, it must be carefully nursed; labour, too, is unorganised, and I think there is little doubt that many of the employers feel that any development of organisation must be checked, and welfare work is used for this purpose. On the other hand, the workers appear to be so prosperous, and so contented with their lot, that they do not seem to feel the need for any third-party

organisation. Again, Labour is uneducated in citizenship, and many of the firms are compelled to adopt methods of Americanisation. The State does not bear so many of life's burdens as the State in this country, therefore the employers feel that they, as individuals, must step into the breach. (This is a point to be remembered when comparisons are being made between the cost of living in the respective countries.) Moreover, a sturdy sense of independence leads men to resent any further encroachment upon their liberties by the State; as one of the Senators said, at the annual Banquet of the New York Chamber of Commerce, to which I was invited: "The State is our fortress and not our almshouse." This sentiment was cheered to the echo. In fairness, too, to many employers in our country it should be remembered that in the post-war period money has been available in America for welfare development, and I fully believe that, had we been in the same favourable position, far wider developments would have been witnessed in the welfare field on this side. At the same time, in spite of our differences, historical, racial, social, geographical, we have very much to learn from each other in methods of modern management.

It seems to me that I cannot do better than conclude this very brief survey of industrial welfare work by quoting the finding of the Industrial Conference which was called by President Wilson in 1920. In the course of the Report it was stated:

"The guiding thought of the Conference has been that the right relationship between employer and employee can be best promoted by the deliberate organisation of that relationship. That organisation should begin within the plant itself. Its object should be to organise unity of interest and then to diminish the area of conflict and supply by organised co-operation between employers and employees, the advantages of that human relationship between them when industries were smaller. Such organisation should provide for the joint action of managers and employees in dealing with their common interests. It should emphasise the responsibilities of managers to know men at least as intimately as they know materials, and the right and duty of employees to have a knowledge of the industry, the processes and its policies. Employees need to understand their relation to the joint endeavour so that they may once more have a creative interest in their work. Industrial problems vary, not only with each industry, but in each establishment. Therefore, its strategic point to begin battle with misunderstanding is within the plant itself. Primarily the settlement must come from the bottom, not from the top."

When the body politic in this country accepts that principle and bases action upon it (and this has been the underlying thought in all that I have said this evening), then, and only then, shall we find that peace in industry of which so much is being spoken at the present time.

DISCUSSION.

THE CHAIRMAN (Sir Robert Hadfield) said that the Society had listened with the greatest possible interest to a very valuable address. He was not exaggerating or wishing to flatter Mr. Hyde when he called it an address by a master mind on this very important subject. No one in this country had studied the various details of welfare work or industrial health more closely than Mr. Hyde. He had had unrivalled facilities for going through the various works in this country, and also in the United States, where he had met a number of leaders of industry to whom he (Sir Robert) was glad to give him letters of introduction. Mr. Hyde had for a long time been Director of the Industrial Welfare Society which had done splendid work in arousing enthusiasm and interest amongst employers with regard to this great subject. He worked under a good master, namely, H.R.H. the Duke of York, who was the President of the Society, and he knew that the Duke had given every possible assistance to the Chairman and the Committee.

As showing its many activities, only a few days ago important meetings under the auspices of the Society were held in London, and there was to be a further gathering on the morrow to discuss the methods and problems which are met with in works. At this meeting a paper would be read by Sir Joseph Burn on pension funds, and one by Mr. Leonard King on sickness and benevolent funds.

It would no doubt be remembered that in December last the Society of Arts held an excellent meeting on a similar subject, when a paper was read by Mr. Warre Bradley, of Messrs. Watney, Coombe Reid & Co., entitled "Industrial Welfare in Practice." Mr. Bradley presented a most excellent paper, and the discussion which followed was of the highest interest, and must have resulted in further attention being paid to the subject both by members of the Society of Arts and by those outside.

He had hoped to have the pleasure that evening of listening to a contribution to the discussion from an important American who had devoted special attention to this subject, Mr. George M. Verity, President of the American Rolling Mill Company, the well-known makers of iron and steel, who employed about ten thousand individuals, and whose net sales for 1926 were about £7,000,000, with a net profit from operations in that year of £900,000. In an interesting pamphlet about this firm, entitled "Twenty Years of Progress," written by Mr. Verity, it was claimed that their rolling mill had made an expansion of no less than 4,400 per cent in the last twenty-six years. That showed what a growing country America was. It could not be hoped to emulate this example over here, but there was no doubt that in the near future there would be developments in the Empire on a much larger scale than at present. He was quite sure that they could come up to their American friends, not only in rapidity but in the celerity of their advance. In a letter he received not long ago from Mr. Verity he stated that they did not use the term "Welfare," as they felt the psychology of the word was bad. They talked instead of "personal relations" and "mutual interest" work, but to his mind this came to very much the same thing. Another form they used in America was "service work."

There were a few words he would like to say about the welfare section in his own firm of Hadfields, Limited, who had devoted much attention to this important service work, and had assisted its own internal organisation by considerable monetary grants for ambulance work, sports and other amusements, including the dramatic and operatic section. In connection with ambulance work he found that in 1926 in this branch something like £1,230 was spent, which covered the cost of various charges in connection with ambulance room attendants and material, motor ambulance service, and grants for ambulance trip and dinner. To give some idea of

the use of the motor ambulance in the various mishaps and accidents which occurred in modern works, it might be mentioned that the ambulances—of which there were two, one in regular use and the other as a standby—ran no less than 3,252 miles in 1926. At the East Hecla Works there was a central ambulance room, open day and night. Distributed all over the works in various shops and offices there were no less than 104 certified St. John Ambulance men, whilst apart from the central ambulance room they had 33 fully equipped first aid boxes fixed in suitable positions around the works. At the Hecla Works they had a central ambulance room, 14 St. John Ambulance men, and 8 first aid boxes. As regards the number and nature of the cases dealt with, it would probably astonish those present to hear that, apart from large numbers of re-dressings, last year the total number of such cases amounted in round figures to no less than 13,000 at the East Hecla and 3,000 at the Hecla Works, or 16,000 in all, averaging 320 per week. This was on a total number of workpeople of between 5,000 and 6,000. Unfortunately, modern industry, notwithstanding the careful precautions taken, did carry with it a certain amount of risk and danger.

A short time ago one of those wretched journals inspired by the Soviet, published in this country for a penny and sold at the entrance to Messrs. Hadfields' works, told how one of the men, very seriously hurt, was left for half-an-hour without attention. This, of course, was a lie from beginning to end, but it showed how abominable were the attempts made to cause mischief between masters and men. As a matter of fact the Hadfield Ambulance attendants were on the spot within two minutes afterwards, giving every possible help.

The great majority of the cases to which he had referred were, of course, only of a minor nature, such as eye troubles, cuts, and burns. The hospital cases from both works last year numbered 181, which it would be seen was a little over 1 per cent. of the total number of cases dealt with. He was thankful to say that no case last year proved fatal, a statement which gave no little satisfaction to his Board and to the many willing helpers at the works. It would be understood that the carrying out of all this work required the constant attention of a number of helpers from amongst the officials, practically all of them honorary, including the chief of the Ambulance Section, Mr. Roebuck, his secretary, Mr. Fielding, the instructors, and Dr. R. G. Selby, the lecturer to the Society, from whom most valuable help was received. Two of the officials had been granted the honour by the St. John Chapter House in London of the rank of Honorary Serving Brothers of the Order, namely, Mr. Shutt, one of the instructors, and Mr. Fielding, the secretary. There were nine persons holding this rank in the whole of Sheffield, and two of them were at Hadfields. The population of Sheffield was now about 525,000, and the number of persons employed in the iron and steel trades 164,000.

With regard to the sports organisation, facilities were provided for cricket, tennis, bowls, football, hockey, and running. The sports ground had an area of 14 acres. The average income of the sports organisation was approximately £390 per annum, and the expenditure £360, but the cost of upkeep, including groundmen's wages, tools and materials, and repairs to buildings, amounting to about £900 per annum, was defrayed by the firm. The average membership was in the neighbourhood of 1,000, and the facilities were available to all who paid a nominal subscription of 6/- per annum. Finally he touched upon the work of the dramatic and operatic section, with its amateur theatrical society. This section was at work all the year round on the study of drama and music. Its principal public function was the production of a musical play annually at one of the local theatres. All the members of the caste were employees of the firm, and a particularly pleasing feature was that

the male members were drawn from most of the departments, and included those taking part in the manual labour of those departments. The last production of this kind, "The Gondoliers," attracted a total attendance for the week of about 4,000. Community singing had recently been commenced during the dinner hour at the works, and on two days a week there was some hearty singing in the games room. Once more he desired to say how much the Society was indebted to Mr. Hyde for his admirable address.

THE RIGHT HON. GEORGE N. BARNES, C.H., said he had greatly appreciated the address. Mr. Hyde spoke with a full knowledge of his subject, and, of course, having that knowledge in his mind, he had been able during his recent visit to America to look for just what was wanted and to make up his mind as to the value of what he saw. The Society was fortunate in having been addressed by one who knew the subject from A to Z. The topic was one of the most important, if not the most important, in the industrial world of to-day. For a very long time in this country industry was under the rule of scientific discoveries and mechanical inventions all directed towards increasing the production of labour and thereby the fortunes of individuals. For a very long time there existed that exploitation of labour of which Mr. Hyde had spoken. It was a ghastly period to look back upon, and it was because our industrial history was marked by this stain that one had to-day a labour mentality which was so difficult to manage.

He was bound to disagree with the lecturer when he told them that in his opinion the rise of class consciousness corresponded with the advent of the joint stock company. He was unable to accept that view. He believed that before joint stock companies came into being, and while the individual relationship between employers still existed, class consciousness had taken root in this country. Class consciousness might be dated from the beginning of the last century when exploitation was most unmerciful, but when the individual employer was in sight of his workmen every day all the year round, and when his increasing wealth and their own stagnant poverty were only too apparent to them. Then it was that class consciousness came into existence in the minds of the working people in this country. Indeed, it might be said that the joint stock company afforded an opportunity for combating class consciousness, because in such companies a large number of people were now substituted for the individual manufacturer or the commercial magnate, and the opportunity was afforded often to the workpeople themselves to become small owners of the stock and to have an interest in the concern apart from their daily labour.

Another factor had been pointed out by an American writer, namely, that the man who now ran a factory was no longer the owner of the factory. The man who managed the factory under the joint stock auspices was very often himself an employee of the company as much as the office boy or the labourer in the workshop. There was growing up in this country, the speaker believed, a fellow feeling between the man who ran the factory and the man who was in the workshop doing his ordinary everyday specialised duties. As joint stock companies developed he hoped their evolution would be in that direction, that the manager of a factory would regard himself not only as a man who was there to make profits for a multitude of employers but as one whose business it was to look after the welfare of the men who were employed under him. At all events it was, as Mr. Hyde had said, an integral part of management.

The speaker himself could go back for fifty years. He had spent twenty-two years of his life in the workshop, where he started at six o'clock in the morning. Fifty years ago the only idea was that of turning out as much work as possible, the

workmen being separated from the management. No wonder the feeling grew up in the mind of the average workman that he belonged to a class apart and subordinate to those who were above him. In so far as that idea persisted to-day—and it did persist—it was at the bottom of all our industrial troubles, and until it was eradicated there was not going to be much further progress along the path of industrial reform. One way of getting over it was for the employer to own up honestly that he was heir to a heritage of trouble left him by those who went before. Employers in times gone by had neglected their duties, and it was as well to admit the fact. Following that admission, if employers now declared that they would do their duty towards those who were working for them, and who in times gone by had been used to make fortunes for them and had built up the industrial prosperity of this country, a way would be opened out of many of the present difficulties. He himself spoke as a trade unionist, and he hoped the trade unions would grow and flourish in this country. They had done much in times gone by. But although he was a trade unionist he believed that the trade unions had often used sledge hammers to crack nuts. The unions had been brought in to settle petty differences in the workshops which would have been far better settled by those on the spot. Moreover, the unions had encouraged the idea on the part of the workman that he had to do a little bit of work and nothing else. He himself would like to see the workman in a position in which he was able to hop about from one job to another and thereby develop his individuality. He hoped that trade unions would develop on those lines. Whatever else might happen, the welfare of Workmen and peace in industry must start in the workshop, and that was why he attached so much importance to workshop committees for bringing together employers and employed to settle the differences appertaining to the workshop, division of labour, demarcation of disputes, and so on. From these workshop committees there would grow a better feeling, which would radiate out from the workshop right through industrial democracy.

There was just one word of criticism he would like to make upon the paper. The author gave some rather extraordinary figures, showing that in 1922 and the two following years something like 1,500,000 working days were lost through industrial disputes each year as against some 20,000,000 working days lost through sickness. He supposed that these figures were correct for the years mentioned, but if the author had gone back to 1921 he would have found, instead of 1,500,000 days being lost through industrial disputes, that 84,000,000 working days were lost, and if he had gone on to 1926 he would have found the figure to be 163,000,000. Therefore it would be well for members of the audience not to run away with the idea that the relation between these two things was as stated in the figures which Mr. Hyde had quoted. This country was suffering to-day from industrial conflicts which, year in and year out, during the last eight years since the war had entailed a loss of more than 30,000,000 days per year on the average. That was a tremendous loss, and a loss which benefited nobody, neither man, woman, nor child. There were those, as everyone knew, who welcomed industrial conflict, not because they expected any immediate benefit to accrue to the workpeople, but because of a crazy idea that if the existing social organisation were toppled over something better would emerge from the ruins. It was discreditable to those workmen of this country who were "doped" with such rubbish. Any change in the existing order would only come about with a change in the man's mental and moral stature and in the degree to which he fitted himself to take part in the conduct of industry, not as a result of brute force. He wished the Industrial Welfare Society all success in its efforts to create a better feeling throughout industry and to impart to the workman the idea that he was a citizen of a great country and belonged to no

subordinate class ; such a class no longer existed among a politically enfranchised people.

MR. W. H. NEVILLE (Chairman, Boilermakers' Society) said that he spoke as a trade unionist, and desired particularly to appeal to any employer who had not started a welfare scheme at least to give it a trial. He himself had worked in factories where there was no industrial welfare scheme at all and in factories where such a scheme existed, and he was firmly convinced from his own experience that the industrial welfare scheme was a great success, both financially for the firm and in respect of health and social amenity for the workpeople. He would like to say a few words as an employee of the Gas Light and Coke Company. This Company ran a welfare scheme on a very large scale. The firm started the scheme first of all with the idea that it would be a financial benefit to get their employees more interested in the works. The scheme was started as a co-partnership scheme, which made the workpeople feel that they possessed some little holding in the concern. But the idea had grown, and the workers now actually owned £500,000 in the shares of the firm. A pension fund had also been started, which gave a man a feeling of security with regard to his declining years. He mentioned the case of one old employee of the firm who by means of this comparatively recently established fund had now a pension of 24/- a week. Another idea which had proved of great benefit all round was the setting up of an awards committee. The workmen were rewarded and encouraged to send along any suggestions for improvements which they thought would increase output or cut down expenses. In his own department he had received two rewards himself for suggestions from the firm during the last twelve months. Then in the case of sickness and distress, there was a fund to which the workers contributed sixpence a week, and from which they received during illness 15s. a week. In the matter of sports the firm was very generous indeed. The sports grounds comprised 100 acres altogether in different parts of London. The employees paid 1/- a year for membership of the sports section, and 1/6 for any particular class of games in which they wished to indulge, so that they could if they wished play tennis every night a week all through the season for 1/6. A recent reunion of employees in East Ham was attended by a record gathering of 22,000 people. One interesting event as showing the good spirit animating the workers was the fact that one of the engineers employed in the firm had recently patented a new kind of coal wagon, and for the last five weeks a gang of twenty-one men had been working their hardest at ordinary rates of pay in order to get ahead with the invention and assure the success of what their own engineer had done. These welfare schemes did make life in factories and workshops more enjoyable in every way, and he hoped that any employer present who had not yet started such a scheme in his works would at least give it a trial.

DR. D. A. COLES (Chairman of the Council of Industrial Medicine) said that he believed the address to which they had listened would go far to spread abroad throughout the British Empire the principles promoted by the Industrial Welfare Society. He was present when the Home Secretary made the statement to which Mr. Hyde had referred, that he would be obliged, if he could not get his scheme carried out voluntarily, to enforce it by regulations. New factory legislation was to be introduced into Parliament in November of this year, and the Home Secretary impressed upon those who were present at the gathering referred to that what he wanted was advice and help. Fortunately, the Factory Bill, though it had given rise to such a great amount of discussion, was one of the few measures that all agreed was long over due. There had been many factory bills in years gone by, and since the consolidating Act of 1901 there had been an enormous number of

Home Secretary's Orders forming now a large volume. What was wanted was a Factory Bill commanding general agreement. He had been interested in the very conservative and constitutional address of Mr. Barnes and he agreed that it was most essential in this question to put aside everything of a party character. Mr. Barnes said that it would be a good thing if a man could "hop about from one duty to another," but the trouble was that the men would not "hop about."

In one year he medically examined 8,000 men, and in asking them whether they could suggest any light work which would be suitable to their physical condition, he was met almost invariably with the answer that they would "rather stick to their own job." But he agreed that if a man were found doing work which was not suitable for him, it was a tremendous advantage to transfer him to some more congenial employment.

MR. E. KILBURN SCOTT pointed out that there was one great difference between industrial conditions one hundred years ago and now. The direction of firms was by men who had been through the works themselves and were likely, therefore, to have a fellow feeling with their employees. To-day it was not so. Very many directors had no interest in the firm except as shareholders. He was at a meeting of an engineering company which had not a single engineer on the directorate. The directors included several of the accounting and lawyer classes. It was no qualification for such a position to have had an Oxford or Cambridge education; indeed it was "ruination" for an engineer to be sent to those ancient Universities; he should be trained at Universities like Leeds or Manchester, where engineering was really a part of University life. It was because attention was paid to these things in America that firms there were so successful.

MISS EUPHEMIA SMITH suggested that the old age pension now given by the State should be made contributory and placed on a broader basis. It should be compulsory for all persons between the ages of eighteen and fifty-five to contribute to an "all in" scheme, which would include not only the old age pension, but insurance against ill-health and unemployment. The pension given might be perhaps up to 25/- a week. She would have it begin at an earlier age than at present, and this would have the advantage that it would cause people to retire earlier, and so leave the way open for younger people to take their places. If this were made a compulsory scheme she thought it would prevent a great deal of poverty and misery.

MR. H. W. CAPELL said that in his experience the difference in social standing between employer and employed or between different grades of employees was still too much emphasised. In his own factory on one occasion he was asked by the management to instruct one of the women workers in a particular job, and he was told, presumably to dispel his objections to teaching a woman the job, that the prospective pupil was not "one of the girls in the factory," but "a young lady who was an artist." It was evident that the employer considered himself of quite a different class from the "girls down there." It was this spirit which had to be combated, as it was a serious impediment to industrial amenity.

MR. MORRIS SELLERS said that it was undoubtedly a fact that the discontent which was apparent in the working classes was due to a lack of interest and of co-operation on the part of employers. He hoped, as a workman, that the work of the Industrial Welfare Society would be made much more extensive.

A vote of thanks was put from the Chair and carried unanimously.

Mr. HYDE, in responding, said that the discussion had been a little disappointing, because he had sorely missed the heckler whom he was hoping to hear. He would like to tell one story about the very distinguished Chairman of the evening, Sir Robert Hadfield. They saw him there that evening sitting in state, but some years ago he (the speaker) saw him under very different circumstances. Sir Robert was then running a race with one of his own foremen on his sports ground, Sir Robert pushing a garden roller, and the foreman being mounted on stilts! With regard to the figures showing the days lost on account of sickness and trade disputes respectively, which had been called in question by Mr. Barnes, he agreed that in 1926 the figure for industrial stoppages amounted to 163,000,000 days, but even this extraordinary figure for an extraordinary year approximated more or less to the time lost every year through sickness. He very much welcomed Mr. Neville's contribution to the discussion. With regard to the point raised by Miss Smith about universal pensions, this matter would involve a great many actuarial considerations, and it would take a long time to explore a subject of such wide-reaching character. Another speaker had touched on the existence of class consciousness between the shop and the office. That was certainly an ever recurring question, and they could only hope that in time a common interest would unite the employees in all the different branches of the firm. They were encouraged to think so because in the past many other hostilities which were due, as this one was, to ignorance had been broken down.

SIR ROBERT HADFIELD said that Mr. Hyde had not quite given the right version of the story of the race. It was he who was on stilts and his opponent who was pushing the garden roller, and after passing the winning post his opponent by accident ran him down and broke one of his stilts.

CORRESPONDENCE.

GUTTERING FOR ROOF DRAINAGE.

Would you kindly bring to the notice of the right persons a scheme for securing a durable and less unsightly type of guttering for roof-drainage, more particularly under tropical conditions where galvanised iron is so much in use, as recommended in a paper I am submitting to the South African Science Association and in communications to the Medical press, in view of the risk of mosquito-breeding around residences? With suitable moulds the principle can be applied to cast-iron.

By cutting out the guttering with converging borders, which need not involve appreciable loss of sheet-iron and by bending the edges parallel to make a 5-inch eave which can *easily* be fixed on a horizontal plane instead of tilting up one end of the gutter, there is a gradual increase in the depth of the gutter towards the down-pipe which is hardly noticeable even with a 1 in 70 drop. Drainage is thus facilitated without unsightliness to the building, resulting in an increased life of the metal. The present system is less scientific, as the section-area should increase with the volume of water from the increased catchment-area. Where possible, there is a drop from each end of a wall towards the down-pipe; but three grades are needed to fix on to each other for long sections. For instance, grade A, cut out 10 inches wide at one end and 12 at the other, fits on to grade B, cut out

12 inches wide at one end and 14 at the other. Grade C, 14 inches and 16, should seldom be required, and there is practically no waste in the making of the smaller grades.

The drop of 1 in 70 is considered desirable for small buildings in mosquito areas ; but the drop is so durable that one of half that amount would be sufficient for towns. Some such plan would greatly improve the appearance of roofs where the gutters at present show much warping and erosion ; though the advantage of heavier metal is well appreciated. I should be very grateful for an opinion on the practical use of the scheme and advice to further it.

F. G. CAWSTON, M.D.,
Member of the Royal Society of South Africa.

FAMILY ALLOWANCES BY BELGIAN INDUSTRIES.

In his report on the Economic Situation in Belgium in 1926 the Commercial Secretary to H.M. Embassy in Brussels devotes a section to social questions, in the course of which he points out that the system of family allowances, which is purely voluntary, has taken firm root in Belgian industrial life, and, although founded only five years ago, is now practically general throughout the country.

In view of the interest displayed in this question in Great Britain, it may be opportune briefly to summarise the object pursued and the organisation.

The object in view is the grant of special aid by the employer to the workman with a family. The allowance is paid directly by the employer, without any contribution by the workman or subsidy by the public authorities.

There are two kinds of allowances. These are: (1) Birth premiums. These vary according to the Caisse from Frs. 100 to 250 for each child on birth. (2) Monthly allowances. These are quite independent of wages, and are generally paid to the wife by postal cheque. They are on the following scale, and vary according to the industry and district concerned :—First child, Frs. 10 to 20 ; second child, Frs. 25 to 40 ; third child, Frs. 45 to 60 ; fourth child, Frs. 60 to 80.

As a general rule an industry or group of industries becomes affiliated to a Caisse de Compensation. This caisse regulates the charges falling on each employer in such a way as to render them equal for each affiliated employer. This regulation is necessary in order to avoid the possibility of employers hesitating to engage a workman with a large family.

Each caisse establishes its own statutes and rules, fixes its scale of allowances, has its own council of administration, and is quite independent. There is, however, a central organisation, the Comité d'Etudes des Allocations Familiales, to which the caisses are affiliated. This central organisation forms a close connecting link, and, either at the request of an affiliated caisse or on its own initiative, co-ordinates the work, draws up statistics, and investigates questions of general interest.

At the date of the report (December) there were 15 affiliated caisses. Two, including that of the Ghent Textile Association, have joined recently. The number of hands employed by the affiliated firms is 224,173, as compared with 152,603 in 1925. If, however, the industries be added, such as the coal-mining industry, which distribute allowances directly, the total number of workmen enjoying the benefit of family allowances is 400,000.

As regards the sums paid out, the monthly average amount distributed by the Caisses de Compensation in 1925 was Frs. 1,015,200. This had risen to Frs. 1,955,591 by October, 1926. The total amount paid out by the caisses since the institution of the system is Frs. 42 million, and, together with the independent industries, over Frs. 80 million. The total distribution for 1927 is estimated at Frs. 40 million.

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FRIDAY, JULY 29th, 1927.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2.)

NOTICES.

MR. HENRY MORLEY'S BEQUEST TO THE SOCIETY.

Information has been received that under the will of the late Henry Morley the Merchant Taylors' Company and the Royal Society for the Encouragement of Arts, Manufactures and Commerce have, subject to the life interest of the testator's widow, his two sisters and his daughter, been appointed the ultimate residuary legatees of the estate, which is valued at about £30,000.

Mr. Henry Morley died on April 10th at his residence in Coldharbour Lane, Brixton, at the age of 82. He had been elected a Life Member of the Society in 1865, and for many years he was a frequent attendant at its meetings. He was also a liveryman of the Merchant Taylors' Company.

Mr. Morley had probably been associated with the West African trade in this country for a longer period than anyone now living. He joined Messrs. Holland, Jacques and Company about 1874, and shortly afterwards became associated with Mr. Taubman (afterwards Sir George Taubman-Goldie), of the Central African Company. This was one of four companies trading in Nigeria, and they were amalgamated by Mr. Taubman into the United African Company in 1879. In 1883 Mr. Morley became secretary of this company, and subsequently of the Royal Niger Company, a post which he retained until 1902.

EXHIBITION OF INDUSTRIAL DESIGNS.

A selection of the work received in the Society's Competition of Industrial Designs will be exhibited, by kind permission of the Board of Governors, in the Indian Pavilion of the Imperial Institute, South Kensington, from July 30th to August 31st, every week-day from 10 a.m. to 5 p.m., and on Sundays from 2.30 to 6 p.m. The Exhibition will be open free of charge, no tickets being required.

INDIAN SECTION.

A meeting of the Indian Section Committee was held on Friday, July 15th, to consider the arrangements for meetings of the Section during the forthcoming session. The following were present :—Sir Reginald Mant, K.C.I.E., C.S.I., in the Chair ; Sir Charles Armstrong ; Sir Mancherjee M. Bhownaggee, K.C.I.E. ; Sir Charles S. Bayley, G.C.I.E., K.C.S.I. ; Sir Thomas H. Holland, K.C.S.I., K.C.I.E., D.Sc., F.R.S. ; Dr. J. A. Voelcker ; Sir N. N. Wadia, K.B.E., C.I.E. ; and Lt.-Col. Sir Arnold T. Wilson, K.C.I.E., C.S.I., C.M.G., D.S.O., with Mr. G. K. Menzies, Secretary of the Society, and Mr. W. Perry, Secretary of the Section.

PROCEEDINGS OF THE SOCIETY.**NINETEENTH ORDINARY MEETING.****DR. MANN LECTURES (Lecture I).**

WEDNESDAY, MAY 4TH, 1927.

BRIG.-GEN. SIR BRODIE HENDERSON, K.C.M.G., C.B., M.Inst.C.E., in the Chair.

THE CHAIRMAN, in introducing the lecturer, said that Professor Dalby would be well known to that audience. The importance of transport would be brought home in Professor Dalby's lecture. Civilisation as it was now known could not exist without transport, and in this country we were blest with a very good system of transport in various forms.

The following lecture was then delivered :—

ENGLISH RAILWAYS.

By PROFESSOR W. E. DALBY, M.A., F.R.S., M.Inst.C.E.,

Dean of the City and Guilds Engineering College, Imperial College of Science and Technology.

English Railways are a means of transport rendered available to the citizens of this country by the genius of George and Robert Stephenson and the many men who worked with them.

An examination of the historical development of the means of transport in a small area of the country will best show how profoundly transport has influenced and is still influencing our civilisation. Fig. I. shows an area of the country

known as the Vale of the White Horse. This valley includes the source of the Thames and shows the site of an old British camp on White Horse Hill, which will be seen at the bottom of the map. The topography of the district is shewn as it existed long before the Roman Conquest.

It will be seen that towns or villages originated on or near the Thames and its tributaries because in those days waterways were the chief means of transport. A glance at the map of Europe will show how river transport has determined the position of many of the great towns on the Continent ; capital towns are strung like beads on a thread along the Danube and the Rhine and the other great waterways of Europe. Roads came next.

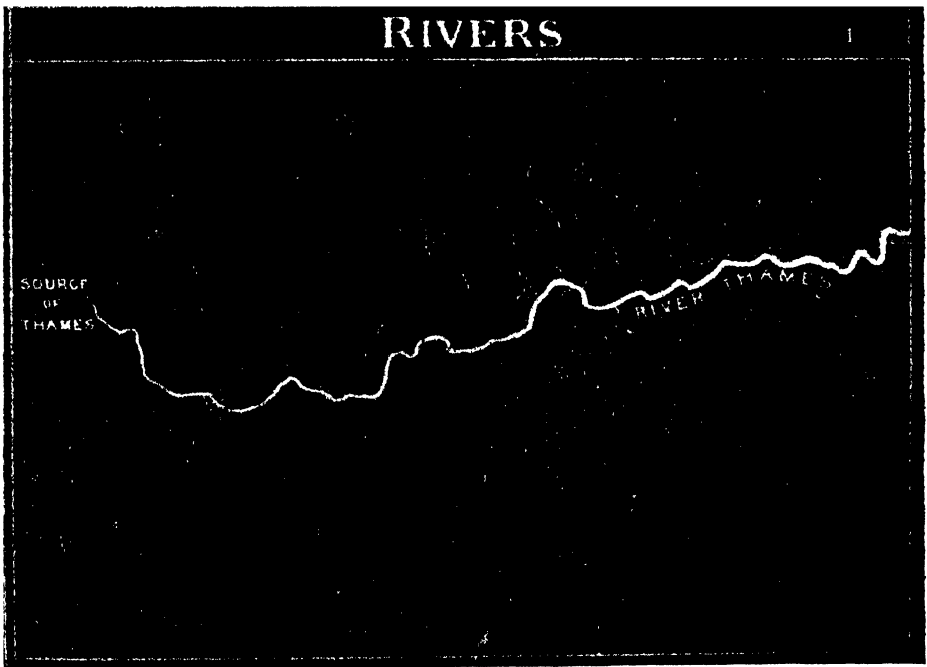


FIG. 1.—The Vale of the White Horse showing its river system.

The Roman engineers were the first to cut their influence deep into our modern civilisation by means of the roads they made. Their camps and towns were connected by roads of such excellence that many of them are to-day still the main roads of the countries over which they ruled. Fig. 2 shows our area (the Vale of the White Horse) as the Romans left it. We see that at Corinum (now called Cirencester) there is a knot in the network of Roman roads which covered England and led through Gaul to Imperial Rome and beyond, to the confines of the Empire on the Euphrates. Think of the profound influence which this system of roads must have had on the shaping of the civilisations of

the countries under Roman rule. Ponder on the imagination of the Roman engineers which led them to undertake and execute such a vast engineering enterprise.

Road making as the Romans understood it stopped when they ceased to occupy the country ; the straight well-made Roman road had no successor until quite recent years ; during the centuries which existed between the going of the Romans and the coming of the motor car roads seemed to have no other purpose than that of winding round large tracts of land to avoid giving offence to the Norman land owners. The state of the roads became worse and worse, and the

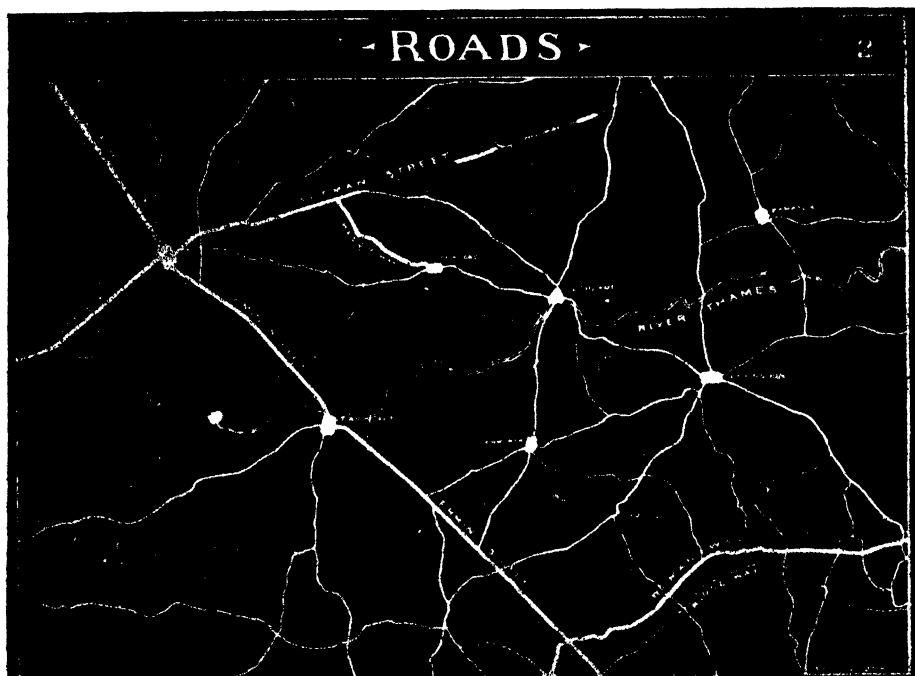


FIG. 2.—The Vale of the White Horse, showing the roads constructed by the Romans.

end of the 18th century (in 1799) found the pack horse the main carrier of goods over the ill-kept roads of England. Various Turnpike Acts secured better roads so that at the beginning of the 19th century the wagon had displaced the pack horse, and the stage coach had displaced the saddle horse.

Fortunately for the national prosperity a new era dawned on July 17th, 1761, when the first Bridgewater Canal was opened. This canal connected Worsley with Manchester.

A horse on the tow path can be used much more efficiently than a horse on the road because on a canal one horse can pull 50 tons at 3 miles per hour but we know that he cannot pull a load as heavy as that along a road. During the

next 50 years England was covered with a network of canals. Fig. 3. shows how the Vale of the White Horse benefited by this change in the method of transport. The dotted lines show the Roman roads and the full lines show the canal system in the Vale. The river Thames has been connected to the Severn by the Thames and Severn Canal, and the Wilts and Berks Canal connects the Thames at Abingdon with the Kennet and the Avon.

The Government of the country, however, took no part in financing or in guiding the growth of the canals which now traverse the country, and the result is seen in a complicated system of waterways, controlled by a multitude

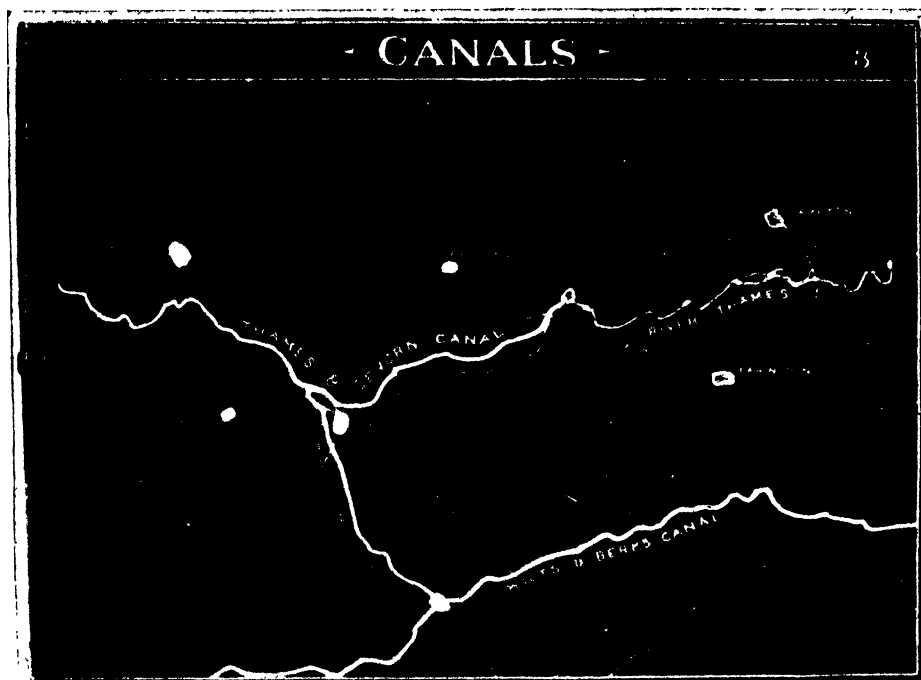


FIG. 3.—The Vale of the White Horse, showing the canals constructed during the period 1761-1830.

of private companies, and no standardisation. The nation, fortunately, was spared the consequences of this haphazard state of affairs, because the towpath horse was practically slain by the steam engine "Rocket" in October, 1829. What may be called the Canal Era lasted from 1761 to 1830. In 1830 the Railway Era began.

Railway tracks were in use in mining districts long before the appearance of the Rocket. Trucks were drawn along these railroads by horses, but steam came into use early in the 19th century. Puffing Billy was built by William Hedley in 1813 for the Wylam Colliery. George Stephenson built an engine in 1814 which pulled 30 tons at 4 miles an hour up a gradient of 1 in 450. But

even in 1824 the general opinion of traders was in favour of canal traction for the general distribution of goods. In an article in the *Encyclopaedia Britannica* for 1824 it is stated that—

“ The application of steam has not yet arrived at such perfection as to have brought it into general use.”

But the trials at Rainhill in October 1829 settled the question definitely and marked the beginning of a new Era.

The Rocket combined three essential mechanical parts never brought together before, namely

1. The multi-tubular boiler ;
2. The blast pipe ;
3. The cylinders directly connected to the axle of the driving wheel loaded so that it would turn on the rail rather than slip.

In its trials the Rocket achieved a speed of 44 miles per hour and brought to transport speed and wide distribution. A locomotive can pull a load up a hill ; but a canal boat must be locked up hill and down hill, and locking is a slow process. It is easier to grade a railway in a country like England than to carry a canal over its hills by a series of locks. To carry the canal at Rochdale over an elevation of 600 feet there were 92 locks in 32 miles.

What may be said to be the first English Railway was the Stockton and Darlington Railway opened in 1825. It was a mineral line operated by steam engines. Then came the celebrated Liverpool and Manchester Railway, the triumph of the Rocket at Rainhill in October 1829, and the opening of the Railway for traffic in 1830.

The financial results of the Stockton and Darlington Railway were so good that a railway mania developed in 1847.

I will not linger over the various stages of the development of the great trunk lines of this country. The names of George Stephenson, Robert Stephenson, Brunel, Sir Daniel Gooch, Sir Richard Moon, Sir John Allport, and scores of others spring to the mind as mighty men of the past.

But we will examine the part of this great network of railways which passes through the Vale of the White Horse. In Fig. 4 you will notice that the railways follow the canals. The canals indicate the directions of the easiest gradients. You will see how the valley has fared during the period of railway construction, and what an extraordinary influence this period has had upon it. In looking at the diagram it will be observed that part of the main line of the Great Western Railway to Bristol crosses the map from east to west, and that a knot is formed at Swindon which may be compared with the knot in the Roman roads at Corinum (Cirencester), which still exists. Comparing the rivers, roads, canals and railways you can see in this small area how engineers have etched their work on the country during a period of 2,000 years.

Let us compare the results. The Bristol express will cross from east to west of our area in 30 minutes. A train of 400 tons will carry 1,000 passengers.

But turn back the clock to the beginning of the 19th century. A stage coach appears on the east. Three hours will elapse before it disappears in the west. It is crammed with 20 passengers. A thousand passengers would require a string of 50 coaches. Again, a coal train from South Wales appears on the west of our map. It carries 1,000 tons of coal. At 15 miles per hour it takes 2 hours to cross the map and disappear in the east. To move this weight of coal across the map in canal boats would require 20 barges, not to mention the time lost at the locks. To go farther back still—to the pack-horse days—10,000

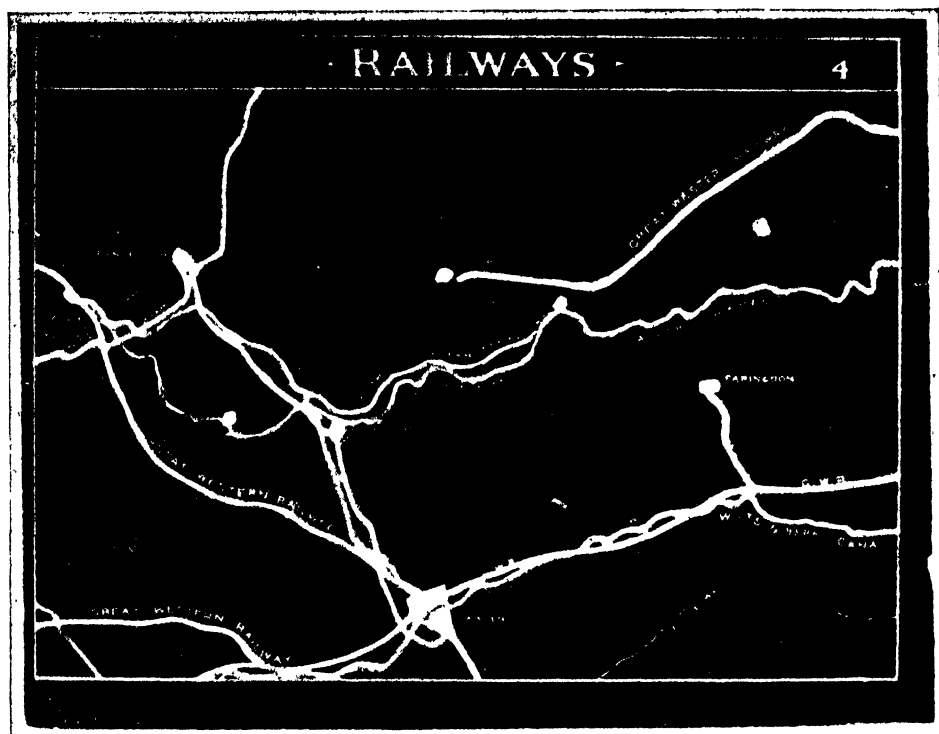


FIG. 4.—The Vale of the White Horse and the railways across it constructed after 1830.

pack horses would have to be brought into service to carry 1000 tons of coal.

I think I have said enough to show what a profound influence railway development has had upon the progress of the nation.

THE DEVELOPMENT OF THE RAILWAYS.

Now let us turn to the financial aspects of railway development. Railway finance can be studied in the returns of the Board of Trade. It is rather an arid study and I cannot recommend it. I will, however, show you by means of a few curves the salient features which have emerged after a detailed study of these admirable returns. I commence at 1850. Fig. 5 shows the total capital

paid up in millions of pounds, and the component parts thereof, for the United Kingdom. The total paid up capital in 1850 was 240 millions sterling. In 1908 it had increased to 1310 millions. It will be noticed that the increase from year to year was gradual up to 1908, certain irregularities having been due to the splitting up of stocks so that the nominal value was increased without increasing the real value. Debentures, Guaranteed Stock, Preference and Ordinary Stock followed one another in much the same proportion. After 1908 I ceased to plot. The War came. In 1922 I resumed plotting. You will see that the capital has not increased; it has dropped owing to the separation from it of the capital of the Irish Railways. The lower curve shows the

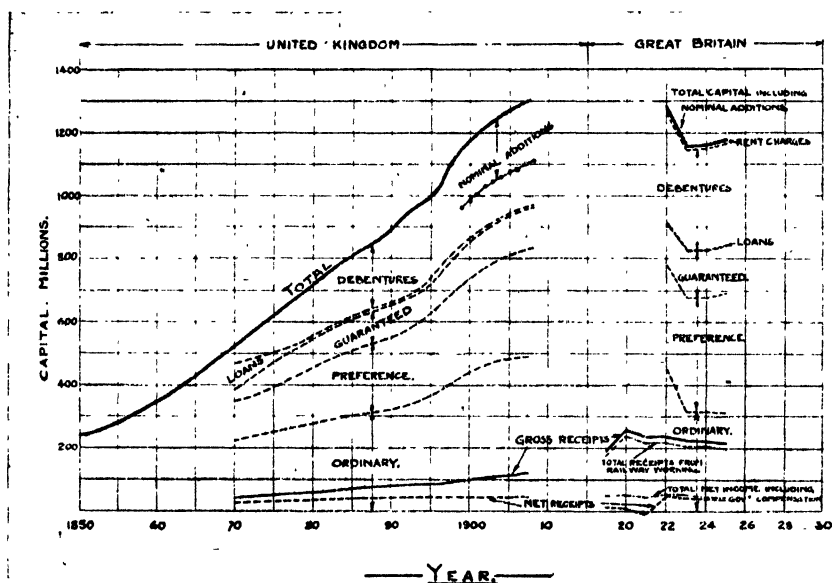


Fig. 5.—Money spent on the railways of the United Kingdom from 1850.

gross receipts for the railways of the United Kingdom. In 1908 it amounted to 20 millions with a net revenue of $43\frac{1}{2}$ millions, corresponding to 3.32 per cent. of the total paid up capital. But this curve shows a melancholy state of affairs after the War. Whilst the gross receipts have risen the net receipts have dropped to nothing and the dividends have had to come out of the reserve.

Fig. 6 will give you some idea of how this money has been expended in the construction of railways. The upper line shows the number of miles of traffic open, plotted against the year, and indicates that there was great activity in construction work during the period 1850 to 1870, followed by a regular but decreasing addition to the mileage from year to year. After the War there is a big drop owing to the subtraction of the mileage of the Irish Railways. The two lower lines of the diagram show respectively the number of

passengers carried and the tons of goods carried from year to year. In 1908 the railways of the United Kingdom carried 1278 million passengers, exclusive of season ticket holders, and 491 million tons of goods. Compared with 1925 this shows that the number of passengers has been maintained on the English Railways alone after subtracting the Irish Railways; but the carriage of goods does not show the normal increase which would be expected from the tendencies established by the curves.

But I need hardly linger over these curves, for at the present time the state of affairs on our railways is abnormal. When we look at these curves and compare the past with the present we realise only too clearly the difficult times

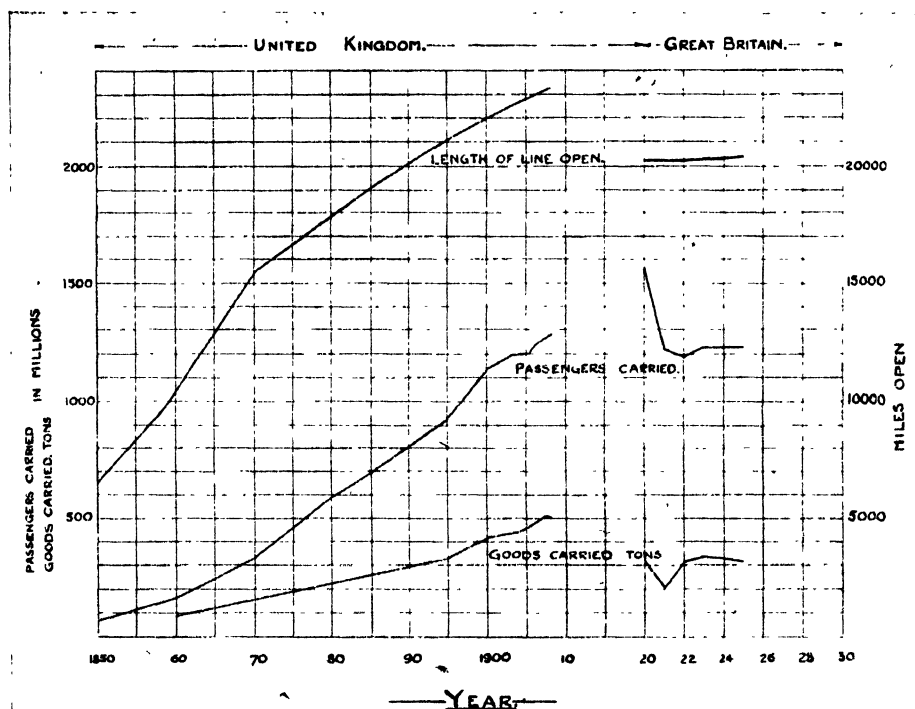


FIG. 6.—Railway mileage constructed in the United Kingdom since 1850.

in which we live. But this is even better illustrated by a diagram which I have devised for showing the cost of running per train mile, Fig. 7. You will see that from 1850 to 1908 the costs as divided between locomotive power, repairs and renewals of carriages and wagons, maintenance of permanent way, traffic expenses, general charges, rates and taxes, etc., were fairly constant with a slight tendency to increase. Taking the average between 1905 and 1908 the cost of running a train was nearly 42 pence per mile, which, as the scale at the side shows, is equivalent to over 6 per cent. of the dividend. It will be seen from the diagram that of this 42 pence, 12.07d is absorbed in

— COST OF WORKING PER TRAIN MILE OF RAILWAYS IN ENGLAND AND WALES. —

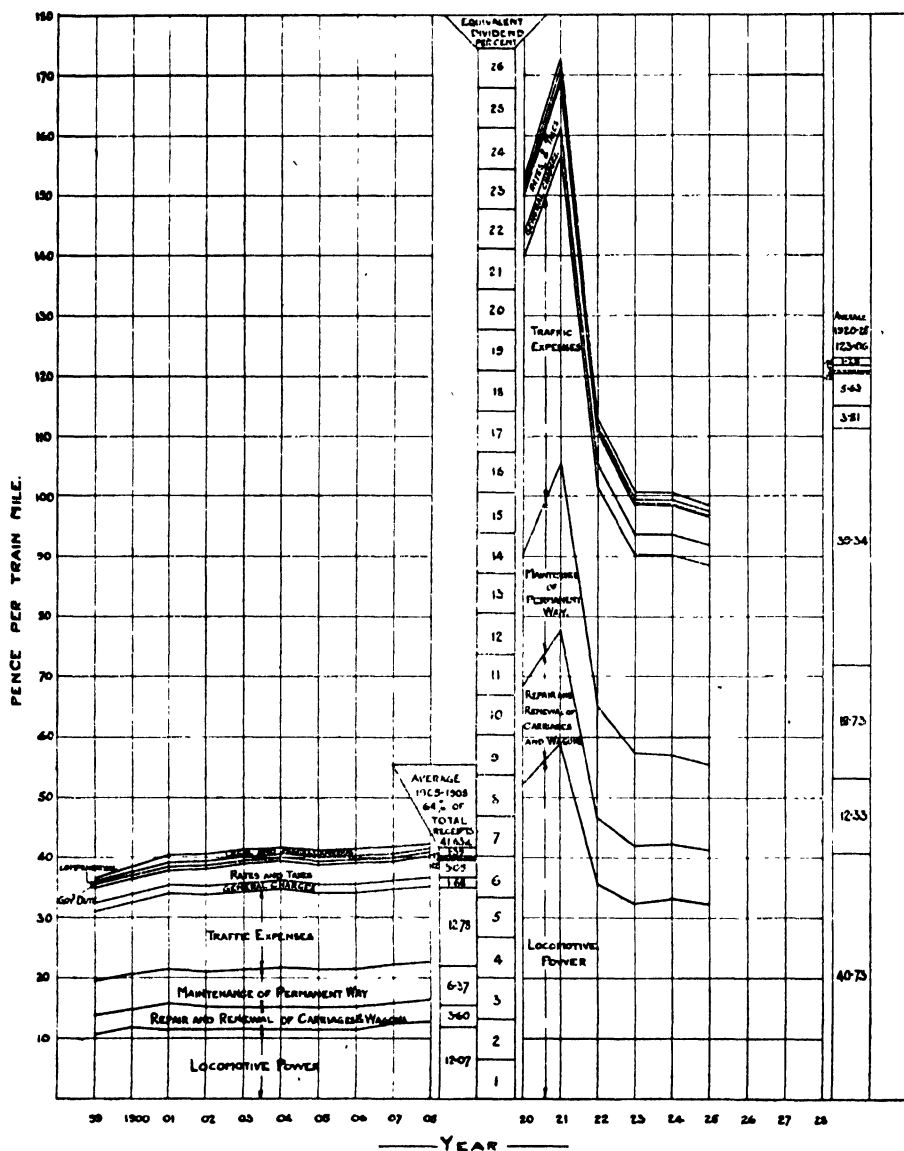


FIG. 7.—Cost of operating the railways per train mile.

locomotive power, 3.6d in repairs and renewals of carriages and wagons, 6.3d in the maintenance of permanent way, 12.78d in traffic expenses, and the rest in general charges, rates and taxes, and other minor expenditures. But these amounts are altogether altered at the present day. Looking at the side of the diagram you will see that the average value since 1920 to 1925

for locomotive power is 40.73d per mile, over three times as much as pre-war costs; repairs and renewals to carriages and wagons 12.33d, that is nearly four times as much as before the War; maintenance and permanent way is 18.73d, which is over three times as much; and traffic expenses have risen to 39.34d which again is over three times as much. There is, however, a tendency for these costs to go down, and an average taken for the following 5 years would probably be more in the region of double pre-war costs.

Having considered the economical aspect of railways and some of their financial problems we will now deal with the technical side of the subject and consider the application of power to turn a wheel.

LOCOMOTIVE POWER.

Power to move a train is derived from the burning of fuel or from water power. In England water power is not available.

Whatever be the origin of the power it ultimately moves the train by means of the driving wheels of the engine.

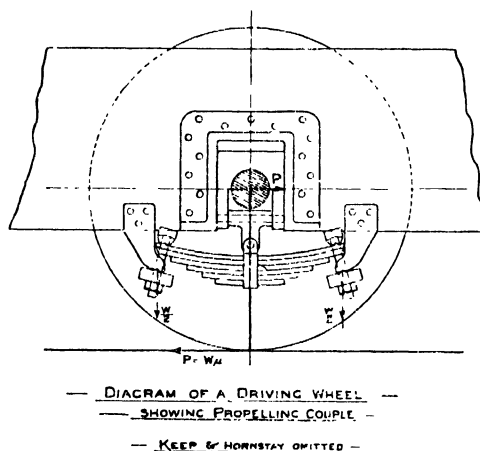


FIG. 8.

Up to 1830 the wheel, one of the greatest inventions of mankind, had been used with few exceptions as a carrying wheel only.

But by that time the application of power to turn a wheel, loaded to produce frictional resistance on a smooth rail against which tractive resistance could be overcome, was brought to a successful issue and another of the great inventions of mankind had been made—the power-driven wheel.

Let us, therefore, spend a few moments in the consideration of this remarkable invention.

Fig. 8. is a diagram of a driving wheel and axle in its axle box. The frame is free to move up and down over the axle box as the springs yield to the inequalities of the rail bed. The other wheels of the engine are carrying wheels.

Let a torque of L ft. lbs. be applied to the axle to turn the wheel either by an electric motor or by a directly coupled steam engine. The turning of the wheel is opposed by a couple, the forces of which are applied, the one at the axle box, the other at the rail. Providing the force at the rail can be maintained, then the equal and opposite force at the axle box pushes the engine along. The engine is propelled against the frictional resistance of the rail, and pulls the train attached to its draw-hook along.

The relations between wheel load and propelling power and frictional resistance are simple.

Let n be the revolutions per second of the driving wheel, and L the couple applied to turn it, in lbs.-ft.

L , the couple, is equal to the product of one force P of the couple and R the radius of the driving wheel, so that $L = 2240 PR$ where P is the propelling push in tons, and R is the radius of the driving wheel in feet.

Then it is easily shown that $\frac{Ln}{87.5} = \text{horse power} = 25 \cdot PRn \dots \dots (1)$

But it is usually more convenient to replace n by the speed of the train, V , in miles per hour. With this change the relation becomes, in round figures, $6PV = \text{horse power} \dots \dots (2)$

For example, suppose that a train, including the engine, weighs 400 tons and that the sum of all the resistances to motion at 50 miles per hour is $1/100$ part of its weight. Then the horsepower required at the driving wheels to propel the train would be, from (2),

$$6 \times 4 \times 50 = 1200$$

The propelling force, P , cannot exceed the frictional resistance of the wheel at the rail or the wheel will slip. The frictional resistance at the rail may be taken at $1/5$ the load, W , on the wheel. Therefore, a pair of wheels loaded to 20 tons would provide a frictional resistance of 4 tons before they would slip. The driving wheel could then exert a propelling force of 4 tons. Beyond that the wheels would slip and the train would not move if it were at rest and it would not accelerate if it were in motion.

To start and accelerate a train a propelling push must be applied many times greater than the tractive resistance.

Some years ago I devised a diagram to solve the problem of the motion of a train so that, having given the power available and the tractive resistances to motion, all the circumstances of the motion could be determined. For instance, the diagram tells how many seconds it takes to attain a given speed, the limiting speed in the conditions of the motion, how far the train will travel from the start in a given time, and how much energy is stored in it at any given time or distance from the start. In fact the diagram is a semi-graphical solution of the general problem of "Motion in a Resisting Medium."

Fig. 9 shows the curves which must be drawn ; No. 1 from a knowledge of the the engine, No. 4 from a knowledge of the resistance to be overcome, including gradients.

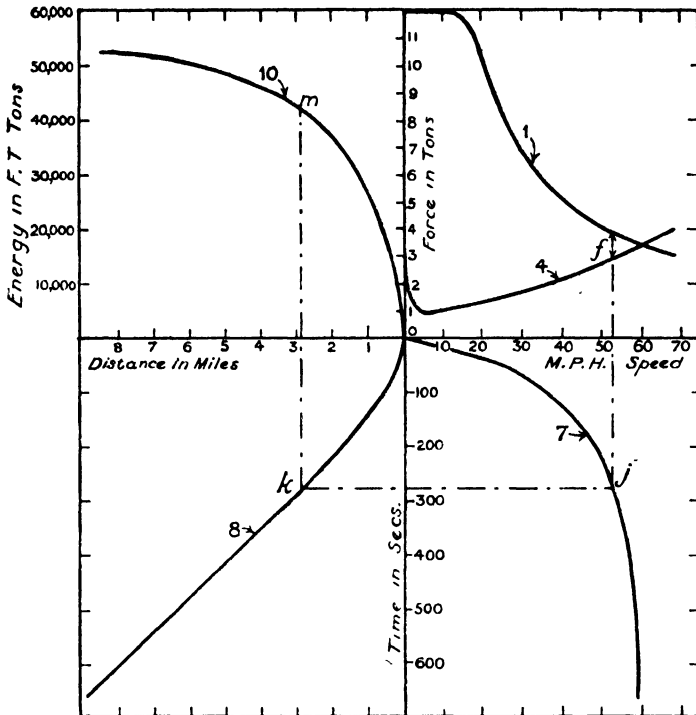


FIG. 9.—Dalby Characteristic Dynamical Diagram for the motion of a train.

The intercept between these curves is the force available for acceleration. I pass over the details of the method and show you the complete diagram drawn for a train of 400 tons, this weight including the 6 coupled express passenger engine attached to it.

From the curves 1 and 4 are derived curves 7, 8 and 10.

Curve 7 gives the speed in terms of the time.

Curve 8 gives the distance in terms of the time.

Curve 10 gives the energy in terms of the distance.

By projecting round with Tee square and a set square the distance can be found in terms of the speed.

For example, a vertical through the speed of 53 miles per hour cuts curves Nos. 1, 4 and 7. The intercept between curves 1 and 4 is *f*, the force available at that speed for acceleration. It is seen to amount to about one ton. A horizontal through the point *j* on the time speed curve intercepts curve 8 in *k* and it

cuts the time axis at 280 seconds. A vertical through k cuts the distance scale at 2.9 miles and curve 10 at m showing that the train stores at the moment about 45,000 ft. tons of energy. The diagram therefore gives this information : that the engine attached to the train is capable of accelerating it from rest up a gradient of one in one thousand (diagram Fig. 9 is drawn to include the resistance up a gradient of one in one thousand) to a speed of 53 miles per hour in 280 seconds, and that it passes over a distance of 2.9 miles in the process.

This method is specially useful in working out the motion of a train that frequently stops, as for example, in our suburban electrical services, where the stations are close together.

Where quick acceleration is wanted therefore the accelerating force, f , must be large. Since one pair of wheels restricts this force to about 4 tons, coupled wheels are resorted to in the steam locomotives. One aspect of the history of the locomotive is the gradual increase in the number of coupled wheels as the demand for heavier trains grew.

Slides were exhibited emphasizing this point. The engines shown on the screen included,

The Rocket.

Lady of the Lake.

Cornwall.

Charles Dickens.

Percursor.

L.M.S. No. 8.

G.W.R. Castle Class.

S.R. Lord Nelson, undergoing her trials.

L.N.E.R. Pacific Engine.

The following table brings together a few details of the most powerful 6 coupled engines of the present day, in contrast with the Rocket.

MODERN LOCOMOTIVES CONTRASTED WITH THE ROCKET.

	CLASS.	TYPE.	CYLINDERS.			Diam. of Coupled Wheels.	of Engine.	WEIGHT on coupled Wheels.	of Engine and Tender.	BOILER.		TENDER.	
			No.	Diam.	Stroke					Grate Area.	H.S. Total.	Coal	Water.
Rocket	Outside Cylr.	0 2 2	2	8"	16½"	56½"	4½		7½	6	137		
L.M.S.	No 8	4 6 0	4	16½"	26"	75"	79	59	119			6	3000
G.W.R.	Castle	4 6 0	4	16"	26"	80"	80	59	119	30½	2050	6	3500
L.N.E.R.	Pacific	4 6 2	3	20"	26"	80"	92	60	148	41½	2930	8	5000
S.R.	Lord Nelson	4 6 0	4	16½"	26"	79"	83½	62	140	33	1989	5	5000

COMPARISON OF PROPELLING FORCES.

	Steam Pressure (lbs per sq. inch)	Calculated from formula (3). (Tons).	One-fifth weight on coupled wheels (Tons).
Rocket	50	0.35	0.85
L.M.S.	180	12.90	11.8
G.W.R.	225	14.20	11.8
L.N.E.R.	180	13.33	12.0
S.R.	220	14.96	12.4

Propelling force in tons may be calculated from the expression,

$$P = \frac{.85 \times n \times p \times l \times d^2}{2D \times 2240} \dots\dots\dots(3)$$

in which—

- n is the number of cylinders.
- p is the boiler pressure in lbs. per sq. inch.
- l is the length of the stroke in inches.
- d is the diameter of a cylinder in inches.
- D is the diameter of the driving wheels in inches.

The formula does not apply to compound engines.

The Pacific type, designed by Mr. Gresley, has 3 cylinders and this arrangement results in a more uniform turning effort than the usual 4-cylinder arrangement with cranks at right angles. I travelled behind an engine of this class in a dynamometer car attached to the 5.40 p.m. from King's Cross on July 3, 1923. The train weighed 515 tons.

In the dynamometer car a group of flat steel plates stretches across the underframe and the draw gear is connected to the centre of this elastic beam. Its deflection is a measure of the pull. This deflection is recorded on a drum. (A modern dynamometer car was illustrated by slides at the lecture).

Part of the dynamometer record is shown in Fig. 10.

Starting from King's Cross the resistance to motion reached the limiting value and the wheels slipped. Sanding caused the wheels to grip and the train started. A pull of 7 tons on the drawbar was maintained until, when emerging from the second tunnel, the wheels slipped again ; but after that the road became drier, the coefficient of friction went up, and the engine exerted a steady pull, falling to 4½ tons as speed gathered, through Finsbury Park.

We are now off the limits of the part of the Dynamometer Record reproduced so that we cannot follow the drawbar pull on the journey. But it went on recording (the complete record was exhibited at the meeting), and I will now ask your attention to a part of the record beginning at the 97th mile post just before passing through Corby, Fig. 11. We found a signal against us and moreover were on a rising gradient. The signal caused the driver to shut off steam. The draw bar pull fell to zero, and the train speed fell to about

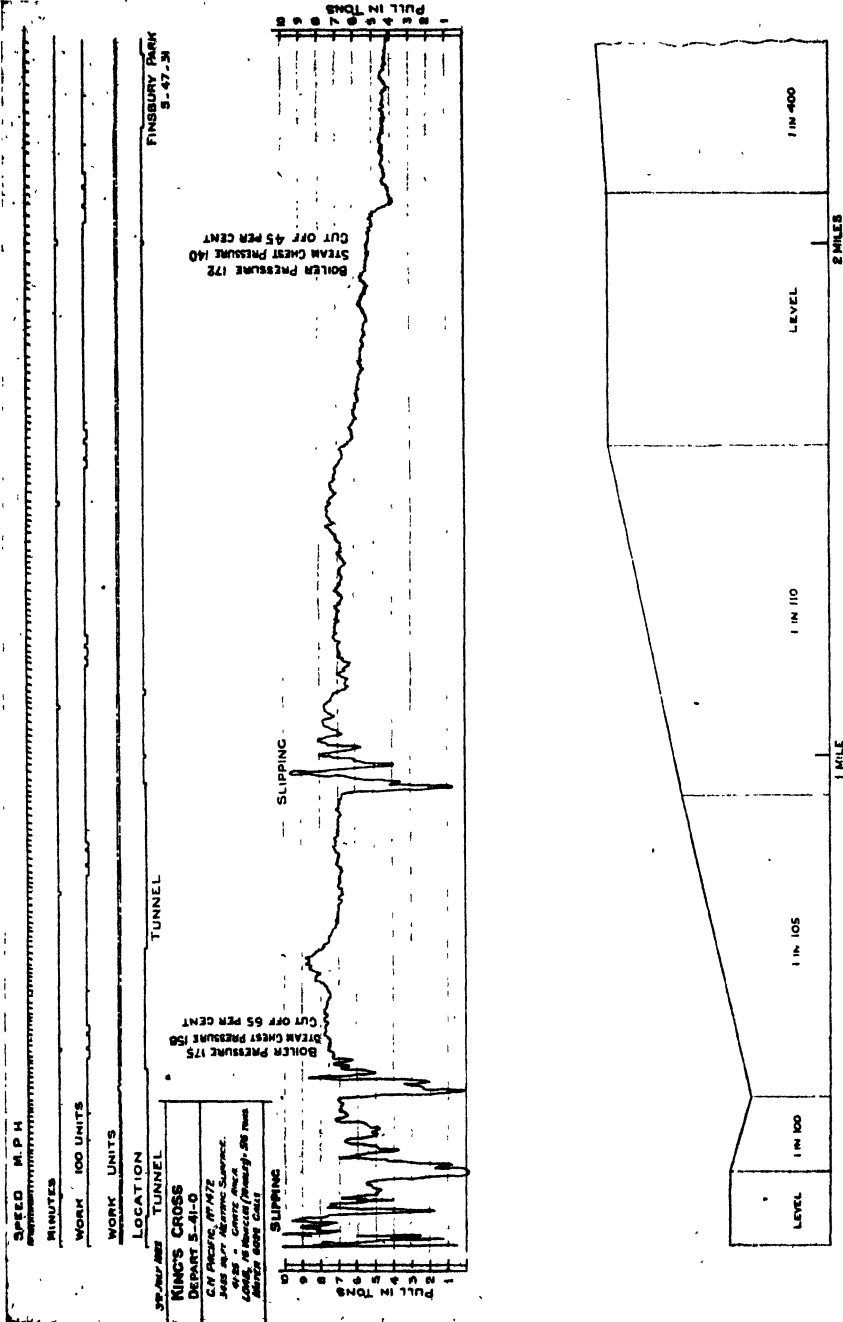


FIG. 10.—Dynamometer record of a start from King's Cross Station.

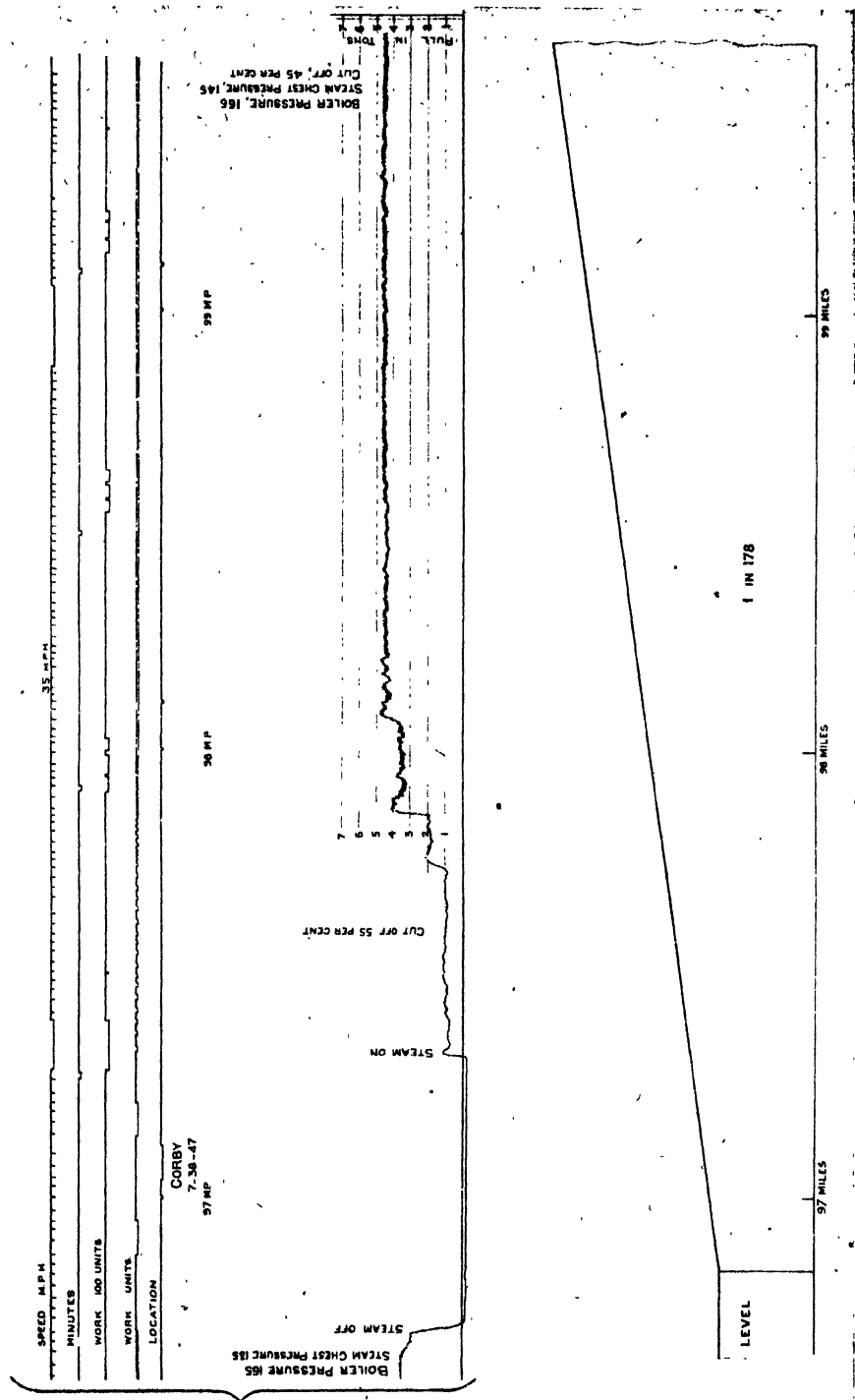


Fig. 11.—Dynamometer record continued; gradient approaching Grantham.

30 miles per hour. The signal fell, steam was put on, and you see the record of the acceleration of the train up a gradient of 1 in 178. The draw bar pull was maintained at about $4\frac{1}{2}$ tons. Assuming the average speed to be 40 miles an hour the horse power at the draw hook was

$$6 \times 4\frac{1}{2} \times 40 = 1080.$$

To this must be added the HP required to drive the engine itself. Estimating this at 600 we have a total HP of, roundly, 1600. We may now estimate the propelling force exerted by the driving wheel from our equation 2. This gives

$$P = \frac{1600}{240} = 6.6 \text{ tons.}$$

Mr. Gresley has given me the average figures of 6 trips of this engine with the ordinary passenger train services between King's Cross and Doncaster.

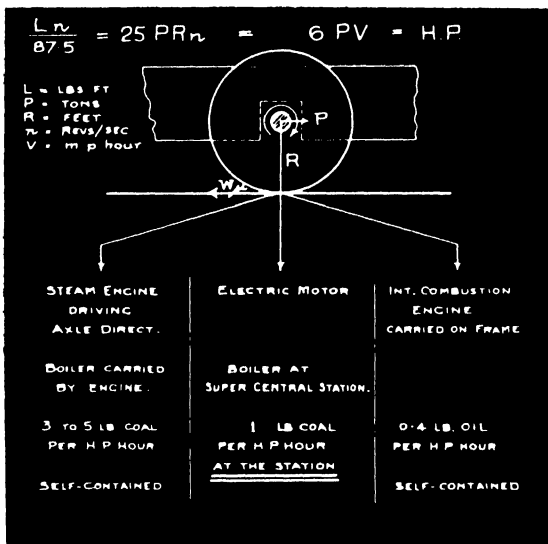


FIG. 12.—Possibilities of development contrasted.

Average speed in miles per hour. 53.7

Average drawbar pull in tons. 2.07

Average Draw Bar HP. 663.

Coal per mile 48.6 lbs.

Coal per hour 2625 lbs.

Coal per sq. ft. of grate per hour 63.6

Water used 38.3 gallons per mile.

2081 gallons per hour.

Let us now consider the possible ways of applying a driving couple to the driving axle or axles.

Fig. 12 gives a brief perspective view of the possibilities.

There is first the locomotive as we know it, a self-contained steam engine. The turning moment is applied directly to the axles and it is varied by throttling the steam pressure on its way to the cylinders, by changing the cut-off in the cylinders by the setting of the link motion, and, in general, by both causes combined. The driver has complete control over the magnitude of the turning couple applied to the axles up to the limit imposed by the power of the boiler. With a wide open throttle and a late cut off the turning couple reaches the maximum it can have consistent with the weight on the coupled wheels.

As the train gathers speed the couple required to maintain the motion is reduced, and the supply of steam to the cylinders is correspondingly reduced. The figures given above show that although it took 7 tons drawbar pull to start the train, the pull dropped to $4\frac{1}{2}$ tons at Finsbury Park, and from the dynamometer record the average pull between King's Cross and Grantham would be about 2 tons.

The work done is paid for in coal burned during the journey. Bench tests made in America on many classes of locomotives show that a locomotive burns from 3 to 5 lbs. of coal per IHP hour. The IHP hour is the unit of work used by engineers in the buying and selling of energy; it is equal to 1,980,000 ft. lbs., or 1414 lb. calories, or 886 ft. tons, or $\frac{1}{6}$ of a ton mile.

The driving axle may be turned by an electric motor deriving its energy from a third rail or overhead wire. The locomotive is no longer a self-contained plant; it depends for its supply on a central station and a transmission system.

From the Mansion House along the District Railway we pass between walls of copper conveying the electric power from Lots Road Station to the various sub-stations for conversion to the pressure suitable for the third rail, from which the train picks up its supply.

The coal is now burnt at the central station. The most economical plant at a super-station may be expected to give a horse power hour for the consumption of 1 lb. of coal. But the energy is at the station, not at the driving axle. Before it can get to the driving axle it must suffer conversion into electrical energy, transmission as electrical energy, and reconversion from electrical to mechanical energy by the motor on the driving axles. By the time all this is done the actual proportion of the coal burnt and turned into work at the driving wheels is about the same as in the steam locomotive. There is little gain, therefore, in electric traction from the point of view of fuel economy; the adoption of electric traction must be decided on other reasons than the saving of fuel to make it worth while. The outstanding reason is that much greater accelerating power can be brought to bear on the driving wheels for a short space of time, because there is no boiler limitation to limit the horse power, and no limit to the number of wheels which may be driven.

The driving wheel may be turned by power from an internal combustion engine carried on the frames. A glance at the comparison shows that there is a great saving of fuel because the internal combustion engine consumes only

0.4 lbs. of oil per BHP hour. It retains the advantage, also, of being a self-contained plant. There is no capital expenditure required for transmission lines, nor maintenance expenditure required for the electric track. Here lies a future. One celebrated firm of locomotive builders, Kitsons of Leeds, have built an internal combustion engine locomotive based upon the Still principle. There are 8 horizontal cylinders connected to a 4-crank axle. The cylinders are divided into two groups, four lead the axle and four are on the trailing side. Steam is used on the axle or inner side of each piston. A relatively small boiler is carried. Full particulars will be found in a paper by Col. Kitson-Clerk in the Proceedings of the Institution of Mechanical Engineers for March, 1927.

For new countries where water is scarce, and where traffic is sparse, there seems to be a future for this kind of locomotive. At present there are the problems inseparable from coupling a high speed engine to a relatively slow speed driving axle; and invention and research are required for transmission gears.

In concluding this first lecture I may mention another outstanding departure from ordinary locomotive practice, namely, the Reid-MacLeod Steam Turbine Locomotive. The engine complete with boiler, steam turbine and condenser, was exhibited at the Wembley Exhibition. The high speed turbine is connected to the driving axles through gearing. A full description of this remarkable engine will be found in the *Engineer* for Feb. 4, 1927.

THE CHAIRMAN said that he took it that most of those present intended to be present also at the second lecture, but on behalf especially of those who might not be able to attend on the next occasion, he desired to offer what might be described as an interim vote of thanks to the lecturer.

The vote of thanks having been carried unanimously, the proceedings terminated.

PALM OIL IN SUMATRA.

The intensive and scientific cultivation of the oil palm on the east coast of Sumatra has been often referred to by both local and foreign writers as Netherlands India's new agricultural industry, and the results achieved in the past six years foster the belief that within ten years the production of palm oil in Sumatra will be of such magnitude that, from the position of a minor export, it will have reached the front rank of principal exports.

According to the recent annual Report by the British Commercial Agent at Batavia, the difficulties encountered by the pioneers of the Sumatra oil palm industry have one by one been overcome. No little credit for the success achieved is due to the scientific research work undertaken by the agricultural chemists of the State Department of Agriculture, working in conjunction with the experimental station at Kampong Baroe, Medan. Planters have also found makers of palm oil machinery ready to meet any suggestions for improvements in the pressing plants supplied, which would tend towards a higher recovery of the oil contents of the fruit.

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*All communications for the Society should be addressed to the Secretary, John Street,
Adelphi, W.C.(2.)*

PROCEEDINGS OF THE SOCIETY.

TWENTIETH ORDINARY MEETING.

DR. MANN LECTURES. (Lecture II).

WEDNESDAY, MAY 11TH, 1927.

BRIG.-GEN. SIR BRODIE H. HENDERSON, K.C.M.G., C.B., M.Inst.C.E., in the
Chair.

The following paper was read : -

ENGLISH RAILWAYS.

By PROFESSOR W. E. DALBY, M.A., F.R.S., M.Inst.C.E.,

Dean of the City and Guilds Engineering College, Imperial College of Science
and Technology.

In the last lecture we took a rapid survey of the importance of Transport to the civilisation of the country with special reference to the rise and development of our railways commencing in 1830. We also looked at the financial aspect of the development of the English Railway system and glanced at the distribution of the cost between the various departments.

We then identified the beginning of railways with the invention of the power-driven wheel and considered a few possible ways of driving a wheel.

To-night I propose to consider a few technical points connected with :

1. The action of a steam locomotive.
2. The steam locomotive and its relations to the track on which it runs.
3. The research work at present in progress to determine the action of the locomotive on a bridge.

(I). THE ACTION OF A STEAM LOCOMOTIVE.

The steam locomotive carries its boiler with it. Its power is therefore limited by the size of its boiler. Each lb. of coal burnt should yield 8000 lb. calories of heat energy (14400 BTU). The actual yield is less than this and varies between 50 and 85 per cent. according to the rate of combustion.

The rate of combustion is measured by "lbs. of coal burnt per sq. ft. of grate per hour." To get 85 per cent. of the possible energy of the coal this rate would have to be kept as low as 30. When the rate increases to 150 lbs. per sq. ft. of grate area per hour about half the heat energy of the coal shovelled into the box is lost by incomplete combustion and by the loss of partly consumed cinders and sparks projected from the chimney top. But the relation of rate of combustion to heat energy produced also depends upon the kind of fuel used. A higher rate of combustion is possible with large lumps of Welsh coal than with coal of smaller grade.

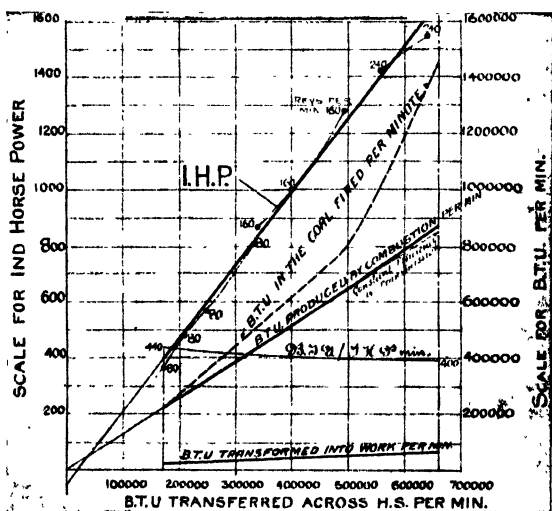


FIG. 13. Dalby Characteristic Energy Diagram typical of locomotive performance.

Each lb. of coal require about 20 lbs. of air to burn it properly. Therefore, as the rate of combustion goes up the speed of the air through the fire goes up until a stage is reached at which the air carries away the finer fuel with it. For example, an average consumption for a modern express passenger engine may be taken at 50 lbs. of coal per mile. The weight of air which must be drawn through the furnace per mile is then $50 \times 20 = 1000$ lbs. The density of air at normal temperature and pressure is 0.08 lbs. per cubic foot, so that 1000 lbs. of air occupies a volume of 12500 cubic feet at NTP. This is the volume of a room 30ft. $\times$ 30ft. $\times$ 14ft., which is about the size of this lecture theatre. If a locomotive is running at a mile a minute and burning

50lbs. of coal per mile it must therefore draw a volume of air equal to the volume of this theatre through the furnace every minute. This prodigious displacement of air is done by the air ejector formed by the blast pipe and chimney. (Illustrations of the combination were shown on the screen).

The curves in Fig. 13 show the penalty which must be paid for increasing the rate of combustion unduly. It is the record of an exhaustive trial made on an Atlantic engine 4-4-2 at the St. Louis Exhibition reduced in a way I devised some years ago to exhibit the energy distribution and transformation in a locomotive and so track down causes of inefficiency. I plot all the material quantities in terms of the heat transferred across the heating surface of the boiler because this is a quantity susceptible of accurate measurement. I use American figures because no data from English locomotives are available.

Curve 1 shows the remarkable property that the IHP is a linear function of heat transferred, however the engine is worked and however the speed is changed; providing that the regulator is kept at a constant opening and the power is varied by the link motion, the law holds. Curve 2 shows the heat energy corresponding to the coal shovelled into the box. Curve 3 shows the heat energy actually produced per minute. This is almost a straight line and brings out the point that notwithstanding the increasing inefficiency of combustion, as the rate of working goes up the proportion of the heat actually produced which passes across the heating surface to the water, remains constant and equal to about 75 per cent.

Next, how much of the heat energy in the coal is turned into mechanical energy by the steam engine? A glance at the Figure shows that to get mechanical energy equivalent to 60,000 BTU per minute, a transfer of 60,000 BTU is necessary and a fuel supply containing 1,200,000 BTU per minute. That is, only 1/20 of the heat energy supplied in the fuel is used to drive the train. A few general and approximate figures may be obtained from this result.

Let x be the number of pounds of coal, of calorific value C , shovelled into the box per mile.

Then, when the overall efficiency is 0.05, the work to propel the train is $0.05xC$ heat units per mile. Reduced to ton-miles, this is equal to $0.05xC \times \frac{1}{8448}$. If C is taken at 8000 lb. calories per lb. (14,400 B.T.U.), this reduces to,

Work done to propel the train $= \frac{x}{21}$ ton-miles, per mile. Or, neglecting

the mechanical efficiency of the engine, $\frac{x}{21}$ is therefore an approximate value of the push at the horns, or equally the tractive force at the rails, corresponding

to a consumption of x lbs. of coal per mile of calorific value 8000 lb. calories per lb.

If X is put for the pounds of coal shovelled into the box per hour, then the relations become

$$\frac{X}{2I} = PV = \frac{1}{6}HP$$

where P is in tons, and V is in miles per hour.

These relations relate the coal actually used and paid for by the work done to propel the train through an overall efficiency of 5 per cent. The efficiency figure, however, varies in value with different conditions of working in the same engine, as will be seen from the diagram, and of course with different engines. The expression, therefore, although not exact, may be useful in estimating overall possibilities.

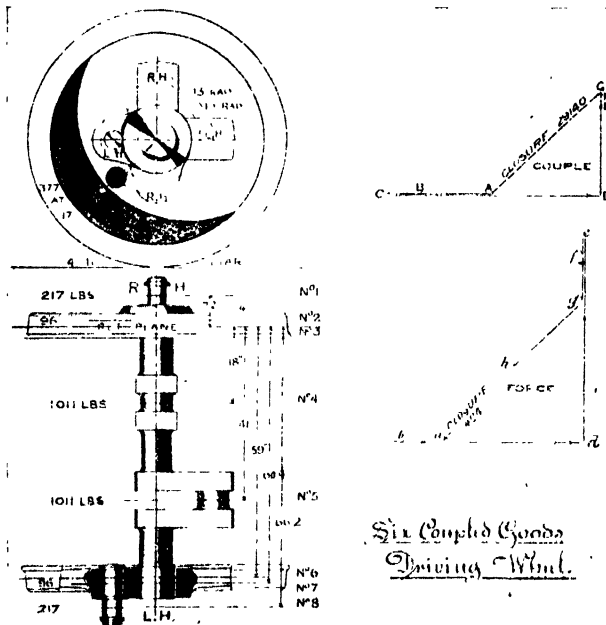


FIG. 14.. Driving axle and its balance weights.

BALANCING.

Let me now proceed to a peculiarity of the locomotive which depends only on the relative motion of its parts. The problem is a purely dynamical one. It arises from the fact that the natural mode of motion is in a straight line at a uniform speed. Force is required to change either the speed or the direction. The locomotive pistons are masses compelled by their connection to a crank axle to change their speed from instant to instant and also the direction of their motion twice per revolution. The forces called into existence for this

purpose appear as reactions on the frame and tend to set the frame in motion, which motion is superposed on the general motion of the locomotive.

Fig. 14 shows the driving wheel of a 6-couple goods engine with a balance weight, shown in black, added to produce reactions on the frame equal and opposite to those produced by the motion of the reciprocating parts and the unbalanced revolving parts. The part of this balance weight neutralising the reciprocating forces introduces vertical forces between the wheel and the rail exactly equal to those which it balances in the horizontal direction. The polygons at the side illustrate the method of finding the magnitude and position of the balance weight, and a full explanation of the method of drawing them will be found in the "Balancing of Engines," by W. E. Dalby, published by E. Arnold.

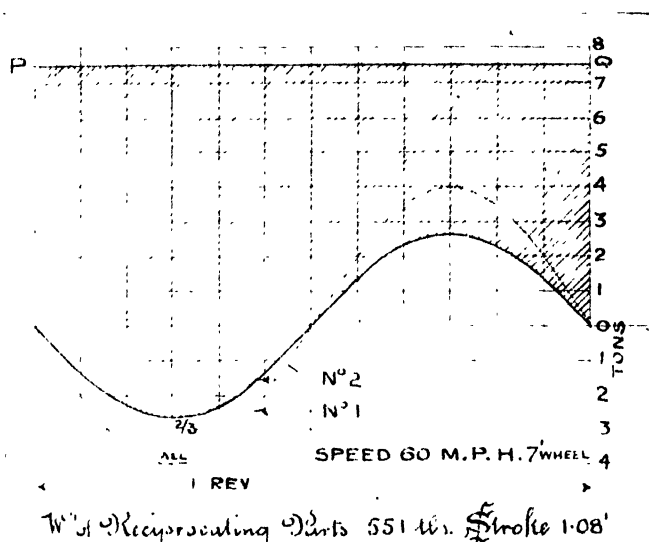


FIG. 15. Variation of rail pressure.

Fig. 15 shows a curve which I drew some time ago to illustrate the amount of variation which may result in practice. Normally the pressure between the wheel and the rail is due to the load on the wheel and it is measured on a weighbridge. This weighbridge load is modified by the rotation of the balance weight introduced to balance the reciprocating parts, and the diagram shows the figures corresponding to an express passenger locomotive running at 60 m.p.h. with balance weights added to neutralise two-thirds of the reciprocating forces. From this you will see that although the weighbridge load is $7\frac{1}{2}$ tons, shown by the line PQ on the diagram, the rail load varies between 10 and 5 tons per revolution of the wheel, Curve No. 2, and if the whole of the reciprocating parts had been balanced then the variation would have been that shown by the dotted

curve No. 1, namely between the limits of $11\frac{1}{2}$ and $3\frac{1}{2}$ tons. Since the force varies as the square of the speed, a condition will be reached with increase of speed in which there will be no pressure between the wheel and the rail; then the wheel will lift off the rail once per revolution. When it returns to contact it hits the rail a blow, called technically the hammer blow. The variation of pressure is referred to briefly as the hammer blow even if the wheel does not leave the rail. I will not inflict a long demonstration upon you by showing you how these forces are calculated, but will show you by means of this model that these forces exist, how they can be neutralised in a horizontal direction and how this produces forces in a vertical direction.

A model was exhibited of a locomotive of the inside cylinder 2-crank type driven by a self-contained electric motor.

Exp. 1. The model was run with reciprocating forces unbalanced, to demonstrate longitudinal oscillation.

2. Balance weights were added and the longitudinal oscillation disappeared.

3. Speed was increased until the vertical hammer blow was actually produced.

When, therefore, we see a locomotive passing over a bridge we know that its wheels are delivering hammer blows to the rail at every revolution. In every day service engines running at high speeds may be producing loads on the rails 50 per cent. greater than those shewn on the weighbridge.

(3) RESEARCH WORK IN PROGRESS.

BRIDGE STRESS COMMITTEE.

The bridge engineer takes all this into consideration when he designs a bridge by making what is called an impact allowance. It has always been tacitly assumed that a train produces a greater stress on the members of a bridge at high speed than at a crawl speed; consequently the impact allowance is the allowance made to cover this supposed kinetic effect, but the question has always been: How much should be allowed? Various formulae have been used, and probably the Pencoyd formula is as well known as any. The Pencoyd formula shows, for example, that whatever the dead load may be for which the bridge is to be designed an increment of 50 per cent. has to be made to cover the kinetic effects of speed for a bridge of 300 ft. span. If the span is 100 ft. the allowance would be increased to 75 per cent.

The formula is $I = \frac{300}{300 + L}$ where I is the impact allowance and L is the span of the bridge in feet. As this is only one amongst many such formulae there was a feeling that something should be done to bring more uniformity into this question of impact allowance. Accordingly the Railway Companies combined with the Department of Scientific and Industrial Research to form a

Bridge Stress Committee in 1923. The Committee has been at work ever since and is now completing a report which will probably be published within the next few months. The Chairman of the Committee has kindly given me permission to speak of some of the points in the investigation.

The object of the research was to determine experimentally the increment of stress on the members of a bridge produced by a train passing over a bridge at various speeds. The method adopted resolved itself into co-ordinating the action of instruments used to measure

- (a) The increment of direct tensile or compressive stress in selected members of the bridge due to the passage of the load.
- (b) The corresponding increment of deflection.

I will illustrate the principle of the method used to ascertain the increment of stress in a selected member by means of this rubber door spring. There are two long needles stuck through the rubber spring to define a distance which is called the gauge length. The application of a load stretches the spring and the needles move apart. The stretch is proportional to the load applied and is therefore the measure of the load applied. Knowing what is called the modulus of elasticity of the rubber we can calculate the stretch if the load is given, or the load causing it if the stretch is given. It is only necessary, therefore, to mark off a gauge length on a bridge member and to measure how much this stretches to estimate the load which produces it. For most steels a stretch of $1/13000$ of gauge length corresponds to an increment of stress of 1 ton per sq. inch. A stretch, therefore of 10 times this ($1/1300$ of the gauge length) corresponds to an increment of stress of 10 tons per sq. inch.

But there is the bridge load itself, so that any stretch measured in this way is in addition to the load which is already on the bridge member, consequently we only measure the increase of load due to the passage of the train, as shown by the additional stretch of the rubber spring caused by the addition of a weight.

Mr. Trench, Chief Engineer of the L.M. & S. Railway and a member of the Bridge Stress Committee, has drawn my attention to a very interesting paper in the Journal of the American Society of Civil Engineers (Vol. LXXXII, 1918, page 1040) which deals with this important question. The engineers responsible for the erection of Hell-Gate Bridge marked a gauge length on each member before it was built into place. When the bridge was up the gauge length would have changed proportionally to the load coming on the member. Therefore the actual extension, or compression, could be compared with the calculated extension or compression. In this way each member of the bridge was converted into an instrument of research for studying the true stress conditions of the structure.

Increments of stretch are measured by means of extensometers attached to the member concerned. Two kinds of extensometer were used by the Committee, viz. the Fereday-Palmer and the Collins.

The Fereday-Palmer instrument is clamped to a boom of a girder. The gauge

length is defined by two points, and the instrument is self-contained. The record which it gives is a photographic one. A source of light within the instrument is focussed on a film driven by clockwork so that a record of extension against time is obtained.

The Collins Instrument produces a record on a cleared standard cinematograph film. The record is scratched in by a point.

I will now deal with the measurement of the deflection of the bridge itself. This measurement depends upon getting a point fixed relatively to the abutments as a datum. The instrument used by the Committee is illustrated by this model (Fig. 16) which I have designed for this lecture in order to show the

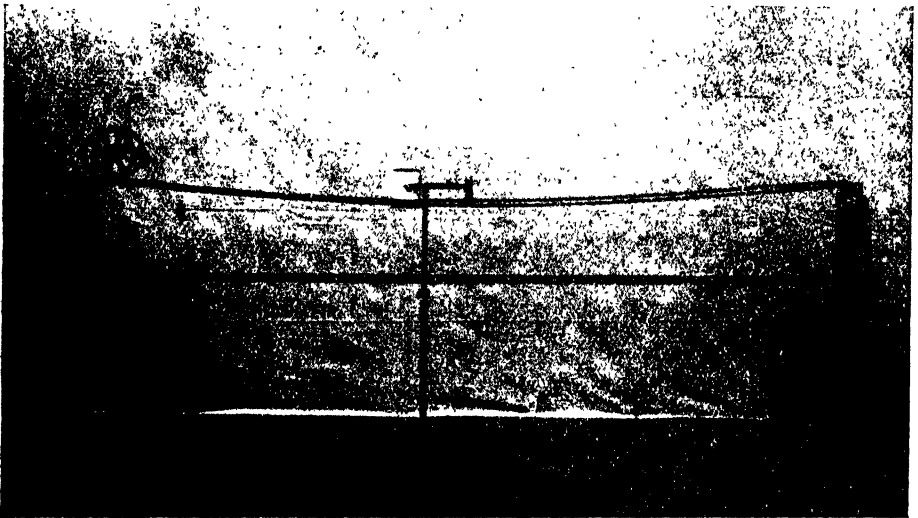


FIG. 16. Model to illustrate the effect of a hammer blow on bridges by recording the deflection.

method clearly. The bridge is represented by two parallel flexible strips of steel connected at their ends and seen in the figure deflected under their own weight. Attached to the centre of the front strip is a drum driven by clockwork. An arm, pivoted to a vertical bar fixed to the strip, carries a pencil which marks the paper on the drum. One point in the arm is pivoted to the steady point. The steady point is the end of a rod supported on the floor. Therefore as the bridge deflects the arm moves about this steady point. When the drum is driven, a curve is obtained showing the deflection against time.

I have here a pair of wheels accurately balanced, seen standing at the end of the strips in Fig. 16. When I place this pair of wheels in the middle of the bridge the weight produces a definite deflection, and a record of this deflection against time is merely a horizontal line on the drum. If I place the wheels at the end of the bridge and allow them to run across it, you see a deflection increasing gradually to a maximum as the wheels approach and pass the centre; and

then decreasing as the wheels pass to the right abutment. (A diagram was taken and passed round.)

The diagram produced is typical of a tractor or carriage passing over the bridge with balanced wheel. The deflection at the centre due to the dead weight of the parts alone is not increased by the rolling across the bridge of these parts. There is, in fact, no kinetic effect. I will recall to your mind an experiment I showed you earlier in the evening in which the variation of pressure between the driving wheel and the rail causes a variation of load above and below the static load as the engine passes over the bridge. Here is a pair of wheels to represent a locomotive driving axle in which balance weights have been added to balance reciprocating parts. I place this pair of wheels in the centre of the bridge and

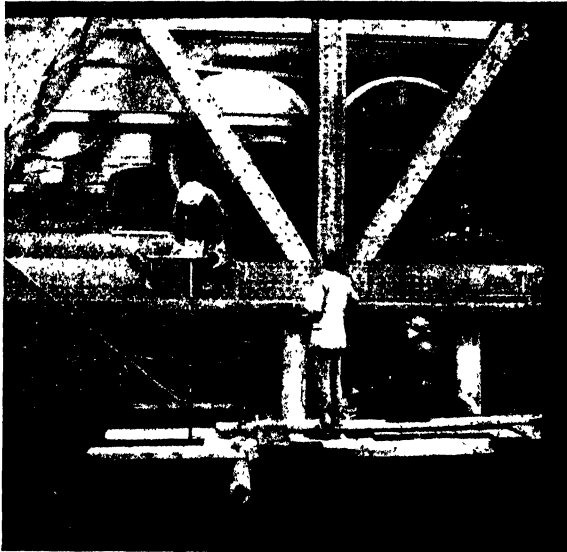


FIG. 17. Photograph showing a bridge with the deflectometer attached.

you see again that the deflection is due to the dead weight of the wheel. I place the wheels at the end and let them run across. You see what happens; the variation of pressure between the wheel and the bridge produced by the balance weights sets up an oscillation in the bridge which is recorded on the drum, (a record was taken and passed round,) and the maximum deflection is considerably in excess of that produced by the mere weight of the pair of wheels or by the motion over the bridge of the pair of wheels which were accurately balanced. The dead load deflection is magnified, and one of the objects of the Committee was to find how much it is magnified, given hammer blow, span and natural period of oscillation of the bridge.

The problem before the bridge engineer, therefore, is to estimate what sort of hammer blow is likely to be delivered to the track by the locomotives which

the bridge is designed to carry so that the maximum increment of stress in the members due to this hammer blow may be allowed for.

Figure 17 is a photograph which I took during the test of a bridge over the river Dove. The deflectometer instrument can be seen fixed to the centre of the lower boom of the bridge. The steady point rod is seen coming down and passing through the hanging platform to the bed of the river. I was fortunate in getting the photograph at the instant the engine was passing over the bridge at a high speed.

Figure 18 is an example of a deflection record produced at the centre of the lower boom of a bridge by a locomotive travelling over it at 30 m.p.h. Looking at the left of the line the horizontal shows the datum line of the deflection being traced by the pencil on the time drum, started just before the engine reached the bridge. The deflection increased to a maximum as the engine approached the centre and decreased as it passed over the bridge. Superposed on the mean line of the deflection curve is the oscillation caused by the hammer blow from the engine. The ripples to the right record the oscillation of the girder itself when the engine had passed off it; this gradually subsided owing to damping influences.

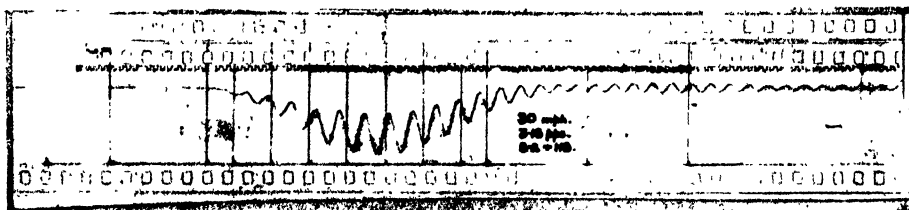


FIG. 18. Typical record.

Slides of many records were shown illustrating amongst other things synchronism between the revolutions of a driving wheel and the natural period of the bridge; the effect of speed; the effect of varying the hammer blow, and the effect of type of engine. In the absence of synchronism the amplitude of deflection is proportional to the resultant hammer blow. Locomotives should therefore be designed with as small a hammer blow as possible.

Unfortunately, the bulk of our locomotives are 2 cylinder engines and as such are bound to deliver a somewhat severe hammer blow depending upon the proportion of the reciprocating parts balanced, the speed, and the type.

A four cylinder engine can be perfectly balanced if locomotive engineers are prepared to accept a somewhat novel series of crank angles. The usual type at the moment has four cylinders with cranks at right angles, so that although the reciprocating masses are mutually balanced for forces, a couple is left in; but the couple does not have a resultant hammer blow.

The difference between the effect of a 2 and 4 cylinder engine was illustrated by records from a bridge on the G.W.R. main line at Langport. The curves

showed that the deflection curve due to a 4 cylinder 4-6-0 type running over the bridge at high speed was very little different from the crawl curve, but the deflection caused by a 2 cylinder 4-6-0 at a lower speed showed ripples caused by the hammer blow of considerable magnitude.

There is however from the 4 cylinder engine an effect which tends to cause torsional oscillations. Although as a whole, as illustrated by running the wheel over the model bridge, a pair of balance weights at 180° (the usual angular distance on a 4 cylinder engine with cranks at 90°) has no resultant action on the bridge, yet each weight delivers its blow to the rail and if each rail were separate from its neighbour and were supported on an independent girder oscillations would be set up in antiphase. That girders of a bridge can oscillate in antiphase is illustrated by the records. The effect can be shown on our model by mounting each strip separately with no end connections, as you see has been done. I have replaced the strips connected at the ends by a pair separate at the ends. Now you see that a pair of balance weights 180° apart can produce violent oscillations in antiphase whilst such a motion of the bridge was entirely absent when the same pair of wheels were running over a pair of strips rigidly connected at the ends.

These remarks and illustrations will, I hope, help to prepare the way for the Report of the Bridge Stress Committee.

It only remains for me to thank you for your attention, and to thank Mr. Gresley, Mr. Maunsell, Sir Henry Fowler and Mr. Collett for the information which they have been so kind as to give me for these lectures.

THE CHAIRMAN said that they had heard that evening and a week ago two lectures full of interest and information for anyone connected with railways. Knowing Professor Dalby as he did, he had expected to hear something exceptional, and he was sure they would agree that that expectation had not been disappointed. Professor Dalby was famed for his great theoretical knowledge, and that theoretical knowledge was accompanied by a wide practical experience. Many people might imagine that, because railways had been running for so many years, new questions could no longer arise, but that was by no means the case. They had found new methods of construction and manufacture, and were continually being met by new demands from the public. New problems were always arising, and new methods had to be constantly introduced. He was particularly pleased at being asked to take the Chair, because he knew he was in for something very interesting and instructive, and also because, being in the Chair, he would be in a position to hear every word, although it was not quite so easy to see everything on the screen. It seemed to him to be quite proper to hold such a meeting as that in the hall belonging to the Royal Society of Arts, because Engineers always considered the practice of their profession to be as much an art as a science. He trusted that they would be permitted to read Professor Dalby's most interesting and instructive lecture in print. It only remained to him—and it was a very great pleasure to do so—to propose a most hearty vote of thanks to Professor Dalby for the lectures he had given.

A week ago he informed them that any observations or comments on these lectures would follow that evening. He did not know how they felt about following a man

like Professor Dalby, but he found it difficult himself, and, therefore, he did not propose to initiate any discussion, because, if he might venture to say so, he thought that discussion of the matters that the lecturer had touched upon would require great consideration, and they had had no opportunity for such consideration, except in regard to the lecture which Professor Dalby delivered a week ago. Those who wished might comment on those remarks, but the points the lecturer had raised were of such great importance that he felt sure that everybody in the room, before committing themselves to any serious criticism, would wish to have time for mature consideration. Professor Dalby shewed them a most interesting statement regarding the combustion of American locomotives, and regretted that he had not got the same statistics in connection with British locomotives. It had been suggested that the British Government should help to obtain the statistics for British locomotives. He thought the British Government would be rather wise to keep away from that, because it might raise a great international question. They all knew that American locomotives were not designed to be economical fuel consumers, but if the British Government dared to produce figures showing how much better the British locomotive engine was than the American, Sir Austen Chamberlain might be called upon to adjust matters! He would not take up any more of their time. He dared not venture to criticise Professor Dalby in any way, but he would like to refer to what happened only yesterday, when he had some results taken by the instrument referred to by Professor Dalby—the instrument designed by Mr. Palmer, who, he was glad to see, was in the room, which was used for testing the members of a certain bridge, and he was pleased to see that the strains that came on the different members of that bridge, as measured by that instrument, were considerably less than were given by the usual methods of calculation.

MR. PALMER remarked that that always was the case.

THE CHAIRMAN ventured to think that that did not prove necessarily that their methods of calculation were wrong. Their methods of calculation had to take into account every unfavourable condition. One had to consider the hammer locomotive referred to by Professor Dalby. One had to consider the bad connections between the rail and the girder on which it rested. One had to take into the calculation the very high wind pressure, and other things, which possibly did not all combine together where these actual tests were taken with these instruments; so that, although these instruments showed less severe results on the bridge than the engineer was able to calculate, he did not think that they necessarily showed that the engineer was so far wrong as might appear at first sight.

A vote of thanks to the lecturer was then put and passed unanimously.

MR. MORRIS SELLERS inquired whether it was possible at any time that oscillation could be so acute that it could endanger a bridge.

PROFESSOR DALBY, in replying, said that Mr. Sellers' question was an exceedingly interesting one. The Report of the Bridge Stress Committee would give much information on the matter. Briefly, synchronous oscillations of a bridge did not build up into oscillations of dangerous magnitude sufficient to break down the bridge because the mass in oscillation was continually changing in magnitude as a train passed over the bridge, and therefore the period of oscillation was continually changing. This was a safeguard which did not exist when the mass was constant.

A vote of thanks to the lecturer having been passed unanimously, the proceedings terminated.

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*All communications for the Society should be addressed to the Secretary, John Street
Adelphi, W.C. (2.)*

NOTICES.

BEQUESTS TO THE SOCIETY.

Under the will of the late Mr. John Bodman Carrington, the sum of £50 has been bequeathed to the Society. Mr. Carrington had been a Life Fellow since 1903.

The Executors under the will of the late Mr. Henry Wagner, who have a discretionary power in respect of the distribution of a sum of £8,000 among charitable and other objects, have allotted £50 to the Society. Mr. Wagner was also a Life Fellow, having been elected in 1874.

EXHIBITION OF INDUSTRIAL DESIGNS.

An exhibition of the work selected by the judges from that submitted at the Society's Annual Competition of Industrial Designs is now being held in the Indian Pavilion of the Imperial Institute, and will remain open every week-day until August 31st, from 10 a.m. to 5 p.m. (Sundays 2.30 to 6 p.m.)

The Exhibition is open free of charge ; no tickets are required. It includes Designs in Architectural Decoration (Wrought Iron Gates for a City Company, Entrance Hall for a Block of Flats, Topographical Drawings, etc.), Textiles, Furniture, Printing and Book-Production, China, Earthenware, and Glass, as well as Designs for Posters, Showcards, Lay-outs, Cartons and Price-Lists.

A Bureau of Information has been established at the Royal Society of Arts in connexion with the competition, for the registration of the names and addresses of exhibitors who desire to obtain employment as designers. These lists are at the service of manufacturers in search of designers.

A report on the competition, including full lists of awards, will be published in the *Journal* at an early date.

PROCEEDINGS OF THE SOCIETY.

CANTOR LECTURES.

RECENT PROGRESS IN OPTICS.

By L. C. MARTIN, D.Sc., A.R.C.S.,

Assistant Professor, Technical Optics Department, Imperial College of
Science and Technology.LECTURE I.—*Delivered January 17th, 1927.*

MODERN APPLICATIONS OF OPTICS.

The Optical Convention of April, 1926, served one very useful purpose (amongst others), namely, that it brought home to many of the general public, and also to the scientific world, the very great importance of optical instruments in modern civilization. Exhibitions are, however, bewildering and tiring ; it is not easy to sort out and disentangle one's impressions. It may be, then, that a review of recent progress in Optics, embodying some of the features of the Convention, will be found of some interest at the present time.

First of all, let us briefly consider the great strides which have been made in the application of optics. Sooner or later, the coming of old age will drive us to the spectacle-maker ; it is good to find that no branch of optics has shown greater progress than his. War injuries to eyesight produced many difficult problems, some of which have been splendidly overcome. If we are stricken with disease, the microscope comes to our rescue in identifying and combating the enemy micro-organisms which may attack us. With its aid the physician counts our blood corpuscles and registers our progress against illness. The microscope is ubiquitous, and also indispensable to the metallurgist, mineralogist, chemist, and physicist.

The chemist makes a vast call on the resources of the optical manufacturer. The polarimeter and refractometer daily check the purity of drinks, food-stuffs and commercial articles. The colorimeter and nephelometer, instruments almost unknown a few years ago, provide extraordinarily sensitive chemical tests. The spectroscope and spectrometer may reveal the presence of substances in traces so minute that chemical methods would fail to detect them.

If the chemist's demands are large, the engineer has claims which are even more difficult to meet. He calls nowadays for measuring instruments of the utmost sensitiveness and precision, which necessarily embody optical parts of the highest quality ; the same may be said of the surveyor and the navigator. Manufacturers are engaged in a ceaseless study of the requirements of these technical men, the conditions under which their instruments are used, and the measure of precision required.

Another class of demands is instanced by those of the military services. Telescopes and binoculars of all kinds, gun sights, dial sights, range-finders, clinometers, periscopes, and the like, all provide their particular problems, and all these actual instruments are monuments of patience, skill, ingenuity, and long experience. Even a search-light or a lighthouse provides an optical problem.

The pure sciences, including, of course, Astronomy, all have their particular requirements, some of which we shall deal with presently.

Lastly, we come to the ordinary man who is, after all, the main optical customer. His demands for spectacles, binoculars, telescopes, cameras, and other photographic apparatus, keep an army of workers busily employed.

These considerations may sound regrettably like a catalogue, but we can now appreciate the multiplicity of the demands made upon the optician. He must be a man of very broad education to deal with a tithe of his work, and the most accomplished of technicians to produce his wares. Instrumental Optics is not a new subject ; it offers no apparent prospect of brilliant discovery such as lie in the realm of Physical Optics. It must always be the kitchenmaid of the sciences, but nevertheless a kitchenmaid can be indispensable, and even charming to some minds. She does not lack work, and therefore should be held worthy of her hire.

It will be necessary in connection with a survey of recent progress to make this first lecture of a somewhat introductory character.

THE ACTION OF OPTICAL SURFACES.

One of the most fundamental characteristics of the majority of optical instruments is the use of a spherical reflecting or refracting surface. Let us study the action of a concave mirror with the aid of a method due to Hartmann. An axial parallel beam of light, as from a star, falls on the mirror (Fig. 1a)

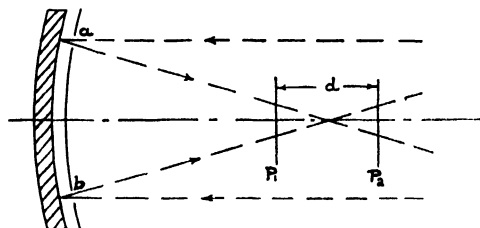


FIG. 1 (a). The Hartmann test.

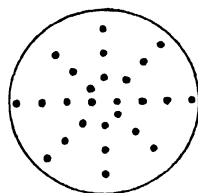


FIG. 1 (b). Typical diaphragm.

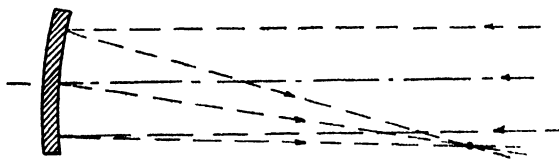


FIG. 1 (c). Method of observing star image used by Herschel.

which is covered with a diaphragm pierced with small circular holes, such as those shown in Fig. 1b. If a small screen be placed in the path of the reflected light near the ordinary focus it will not intercept much of the incident parallel beam. On the other hand, we can, by moving the screen to and fro, soon establish the fact that the light reflected through each aperture is travelling in a fairly well-defined path, and that the paths are closely congruent in one region. The screen may be replaced by a photographic plate for obtaining a permanent record.

Confining attention for a moment to a single pair of apertures a and b (Fig. 1a) the centres of the corresponding traces on photographs taken in positions P_1 and P_2 are found at distances l_1 and l_2 respectively. Hence the distance of the crossing point from the plane P_1 is given by $d.l_1/(l_1 + l_2)$, where d is the interval P_1P_2 . In this way the focus for any zone of the mirror may be found.

The method was originally developed for testing object-glasses of telescopes, and some recent developments of it will be dealt with in the next lecture. We may conclude from such an experiment that the mirror surface can deflect the path of the energy in the incident light so as to concentrate it into a small region. The same is true if the mirror be slightly tilted so that the focus falls just outside the incident beam; it is thus possible to observe the concentration with an eyepiece of powerful magnification. When the diaphragm is still in place the region of greatest concentration of light may be of very considerable size, and this is true if all apertures but one are covered, but when the diaphragm is removed a very different appearance results. The light of the image is

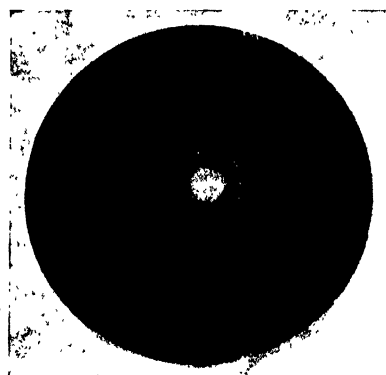


FIG. 2. The "Airy" Star-disc.

gathered into a tiny circular disc which, when greatly magnified, exhibits the appearance of Fig. 2. Since the concentration is so much greater in the latter case it appears that the path of some of the radiant energy has been altered by the removal of the diaphragm. Careful experiment with an "artificial" star (a very small source of light) shows that the size of the image disc is

smaller for blue than for red light, both with the diaphragm in place and without it ; in fact, it is very much better to use monochromatic light than white light, even for testing a mirror, because the discs are much more definite. Thus the conception of " rays," which strictly obey the laws of reflection, as the rigid lines of energy flow must be abandoned ; the same holds good with regard to cases of refraction. The difficulty of reconciling such facts with the corpuscular theory of radiation led long ago to the adoption of the undulatory theory, and we shall see that the fuller realization of the meaning and consequences of the latter theory has been the basis of the most significant recent advances in instrumental optics.

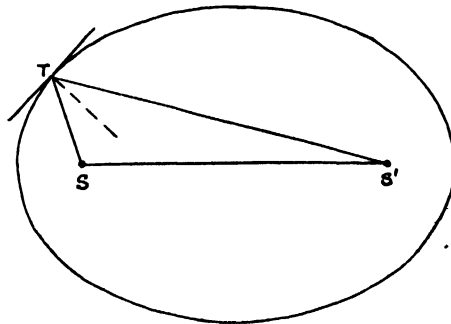


FIG. 3 (a). Elliptic reflector.

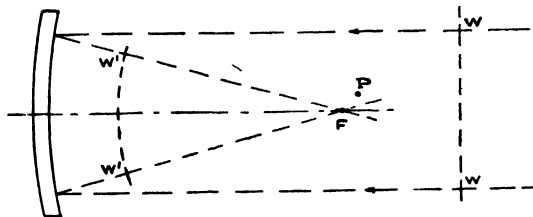


FIG. 3 (b). Parabolic reflector.

Any gardener can mark out an elliptical flower bed with a loop of string passed over two sticks S and S', Fig. 3. He could conclude, therefore, that the actual straight paths ST and TS', where T is a point on the circumference, always add up to the same amount. By spinning an ellipse about the axis SS', an ellipsoidal *surface* can be traced for which the same would be true, i.e., the constancy of the sum of the two paths from the foci S and S', to any point on the surface. Geometry shows further that ST and S'T make equal angles with, and are co-planar with the normal to the surface at T.

Imagining a reflecting surface of this type, it will be understood that a pulse of radiation originating from S, and spreading simultaneously in all directions with the same velocity, will arrive at S' simultaneously from all directions after a single reflection ; the convergent wave front will be spherical and

centred at S^1 . It is found in practice that a small source of light near one focus will produce a concentration of light near the other.

When the distance between S and S^1 is indefinitely increased we have the limiting case of the well-known parabolic reflector, Fig. 3b. WW is the incident plane wave, and W^1W^1 the convergent wave with its centre at F . All ray paths between WW and W^1W^1 have the same length. On Huygens' principle, all points of the medium situated in a wave front may be considered to be the centres of new elementary disturbances; thus the effect at a point P near F can be found by adding the elementary disturbances from W^1W^1 .

Now it has been shown that, in the cases above, the formation of a focus through the congruence of close meeting of ray tracks is accompanied by the condition of an equality of optical paths. Is this equality a fundamental factor in the action of the optical system?

Leaving the idea of a single pulse, and considering periodic waves, it may be considered that two equal and similar disturbances will, under suitable conditions, completely cancel each other's effects when they are relatively retarded by half the periodic time; on the other hand, if they arrive as it were "in step," the amplitude will be double that due to either acting singly. If they are represented by "simple harmonic" displacements, the effect is shown diagrammatically by Fig. 4a. When the time retardation is a quarter of the period (Fig. 4b) corresponding to a displacement of a quarter of a wave-length, the resulting amplitude is still about three-quarters of the maximum.

A simple experiment can be carried out in which two swinging weights impart two independent forced vibrations of long period to the lath from which both are hanging. The motion of the end of the lath, which carries a lens, is

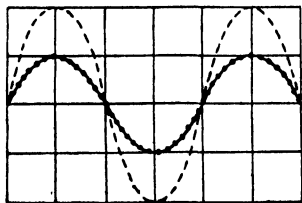


FIG. 4 (a).
No difference of path.

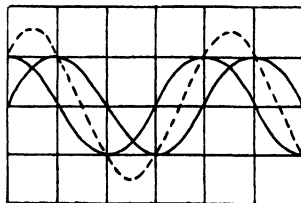


FIG. 4 (b).
Quarter of a wave-length path difference.

registered by a simple optical device in which the lens projects an enlarged image of the filament of a small electric lamp. The motion of the filament image registers the combined vibration due to the two swinging weights. If the latter swing in opposite phase, the image is stationary, provided the amplitudes are equal. If one weight starts when the other is in the middle of its swing the resultant amplitude is less, *but not greatly less*, than when each starts in the same direction at the same instant.

Reverting to the case of the parabolic mirror, and regarding the disturbance at the focus as the resultant of elementary disturbances derived from all points

in the convergent "wave-front" W^1W^1 , which is now regarded as the locus of vibrations in the same phase, it will be understood that anything which retards one disturbance with respect to the others will cause a diminution in its contribution to the total amplitude. The convergent wave-front will no longer be spherical if such path differences have arisen. If there is simply an increase d of the geometrical path, the time retardation is d/c where c is the velocity. If T be the periodic time, the retardation will be d/cT periods, or d/λ , where λ is the wave length. The diminution of the amplitude contribution will not be great unless d/λ is greater than $\frac{1}{4}$, or $d > \lambda/4$.

The retardation may, however, be caused by transmission through a thickness D of medium in which the velocity is reduced to c/N . The time taken to traverse the medium is thus $D.N/c$, which corresponds to DN/cT periods. Hence the optical path must be computed by multiplying the thickness of the medium by the "refractive index," N . The *relative change* of optical path caused by the introduction of a thickness D of medium of refractive index N , which must be traversed in place of the previous stratum of air, say, is therefore $(N-1)D$.

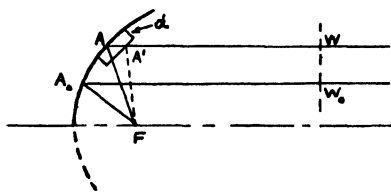


FIG. 5. Effect of surface elevation.

Imagine a geometrically perfect reflecting surface to be shown by the thick parabola in Fig. 5. If WW_0 is the incident wave-front, the paths WAF and WA_0F are identical. Suppose now the surface at A is pushed out over a small area to an elevation d above the former level. The disturbance travelling along the direction WA first meets the reflecting surface at A_1 , which can now be considered to be a secondary disturbance centre which will contribute to the amplitude of vibration in the focus F . How will the contribution be affected by the change of path? An easy calculation shows the relative path difference to be given by $2d \cos i$,* where i is the angle of incidence. Provided that is less than $\lambda/4$ the contribution will not seriously diminish. The formula shows that the allowable value of d is greater, the greater the angle of incidence, and it appears that greater values of d are allowable with longer wave-lengths. A surface which is partly polished will thus reflect red light more regularly than blue light; this effect has been used by French to estimate the state of fineness of a surface by finding the angle of incidence at which the red reflected image can just be observed.

*This expression, and the following one for the case of refraction, are approximate only.

In the case of a transmitting surface, glass to air, say, the path difference which arises through a similar elevation, d , of the surface may be written $d(N - \cos i - \cos i^1)/\cos i$, where i and i^1 are the angles of incidence and refraction in glass and air respectively. When the emergence is normal to the surface this becomes $d(N-1)$, or approximately $d/2$ for crown glass. Hence d should not exceed $\lambda/2$; the requirements are not so strict as in the case of a reflecting surface, for with *reflection* at normal incidence the maximum differences of level should not exceed $\lambda/8$. This discussion explains why refracting telescopes still compete successfully with reflectors in spite of the many obvious advantages of the latter type; it is easier to obtain the required regularity in the optical surfaces.

The value of $\lambda/4$ is only a rough guide; if the residual path differences can be brought well below this limit so much the better. It is instructive to bring a sharp edge, such as a knife edge, just across the focus of an astronomical object-glass, and then to examine the appearance of the lens by any light which just escapes passing through the circular focus disc. Under some circumstances it is not uncommon for the surface to exhibit the marks usually attributed to the tool in the grinding or polishing process as is shown by Fig. 6. The marks are totally invisible otherwise, but they have

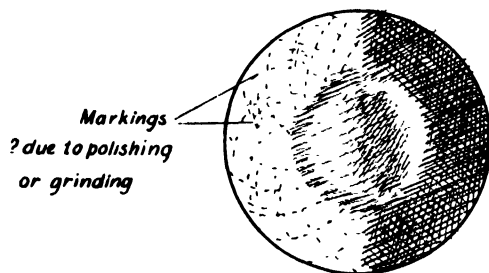


FIG. 6. Sketch to illustrate appearance of telescope object-glass under the Foucault test.

scattered a very small amount of energy away from the general concentration. The wave-length of the brightest part of the visible spectrum is about half a thousandth part of a millimetre, .0005 mm., and for satisfactory *mirrors* the irregularities should not exceed 1/10th of this, which calls for accuracy within .00005 mm. High accuracy is especially required for use with ultra-violet radiation of which the wave-length may be .0002 mm. or even less; even in the refracting surfaces of quartz lenses for ultra-violet work the maximum differences of level should be much less than .0001 mm. A great deal, therefore, depends on a thorough understanding and command of the grinding and polishing processes for optical surfaces; with this in mind we commence our real survey of recent optical progress.

OPTICAL POLISH.

In 1907 G. J. Beilby* described researches on the nature of the polishing

* *Trans. Opt. Soc.* 9 (1907) 22.

process; he distinguished this as very different from grinding. Herschel had believed that the final polishing was merely a very fine grinding, the direct continuation of the process by which, using finer and finer grades of emery, the outstanding irregularities of a surface are worn away by the actual removal of material. Beilby showed, however, more especially with regard to the polishing of speculum metal, that the polishing action consisted, in part, of a flowing action which could cover over the irregularities of the surface. The skin of the material, he concluded, owed its nature and stability in all cases to the surface tension, a conclusion markedly different from that of Lord Rayleigh, whose view in 1901 was that the polishing of glass consisted in an almost molecular wearing away of the highest parts of the surface, and who had supported this view by proving that a thickness of glass equivalent to six wave-lengths of light was removed during the polishing, as distinct from the fine-grinding, process. J. W. French, writing in 1916,* suggested that the surface layer of a polished piece of glass consisted of a portion which had been caused to flow, more or less, under the strong surface forces of the polishing operation. This layer, which he termed the " β layer," was considered, from evidence based on the study of fire cracks, to be about eight wave-lengths deep.

In more recent work by the British Scientific Research Association, the depth of the deepest pits in a finely-ground surface was examined microscopically. The results showed that irregularities of the order of six to eight wave-lengths or more are present in such surfaces, thus indicating again that polish is only complete when the surface is removed to the depth of these deepest pits, when Lord Rayleigh's observation is borne in mind.

F. W. Preston† in 1921 expressed the view that the surface of finely-ground glass is of the nature of a "flaw and fissure complex"; in other words, the surface skin is a layer of finely "cracked" material. The polishing action would then consist in the removal of the fissure complex. In such a "grey" surface there are probably (so it is suggested) a certain proportion of fine cracks slightly wedged open by the displacement of parts of the material. This is a possible cause of the strain first observed by Twyman.‡ The action of polishing allows these fissures to close up; when their width becomes much smaller than a wave-length of light they cease to be visible. We may observe that it may not be necessary to polish down to the level of the deepest fissures, but their effect would be relatively greater with ultra-violet radiation. The existence of residual structure in a polished surface is revealed by light etching with hydro-fluoric acid; the marks often show a similarity to those shown in the Foucault test, and it is quite possible that these latter may sometimes be due to sub-surface structure.

* *Trans. Opt. Soc.* 17 (1916) 24.

† *Trans. Opt. Soc.* 23 (1921) 141.

‡ *Proc. Opt. Convention* (1905) 78.

Many other experiments have been made, including observations on the polishing of "flashed" and "platinized" glass surfaces; they seem to indicate that, in spite of the evidence of surface flow which Beilby adduced for the case of polish in metals, the flowing action is of much less relative importance in the polishing of glass. If it is necessary, then, that the wearing down of the surface must proceed to the level of the deepest pits, at least, it becomes of great importance to ensure that the abrasives used, especially in the fine grinding of glass, shall not occasionally produce pits which are much deeper than the average ones. The ordinary emery and carborundum in use a few years ago, no matter how carefully graded, were apt to fail in just this manner by producing pits which might be as much as fifteen wave-lengths deep; this increased disproportionately the necessary time of polishing. The researches of the British Scientific Instrument Research Association, under the direction of Sir Herbert Jackson, led to the production of the "Sira" abrasive, the most valuable characteristic of which is the uniformity of the grain which it produces in the smoothed surface. When the abrasive is in action it maintains its cutting power and uniform rate of glass removal in a manner markedly superior to ordinary emery or other abrasives of the same size, the grains of which become rapidly broken down. When this new abrasive is used the depth of the pits in a finely smoothed surface is not more than six to seven wave-lengths. As a result, the time of grinding can be decreased by two-thirds, and that of polishing by one-third, as compared with the previous time when using ordinary emery and rouge. When grinding with the ordinary abrasives, the finer smoothing is accompanied by the breaking down of the particles of the emery or carborundum, hence the addition of fresh abrasive is not advisable after a certain stage, but, owing to the uniformity of its action, it is always possible to feed on more Sira abrasive. The same Research Association is also responsible for a polishing rouge which is of great purity, and free from the marked tendency towards adhesion or sleek-cutting properties found in impure specimens. Such researches are good examples of the way in which various optical operations, at one time imperfectly understood, have recently been brought under control.

Recent years have witnessed considerable departures from traditional methods in the roughing, grinding, and polishing processes. The firm of Messrs. Taylor, Taylor and Hobson, Ltd., of Leicester, has been one of the foremost in improving these operations. Many lenses and prisms are now moulded, and we shall discuss this in the next lecture, but to be absolutely sure of obtaining satisfactory freedom from strain, etc., the lenses are best cut from a tested slab. The cutter is a hollow cylinder of soft iron, rotated at a high speed, the cutting edge of which is charged with diamond dust; this cuts circular discs out of the slab. Constant lubrication is necessary. This method is a contrast to, and much more economical than, the old practice of "shanking" down a square disc. The accuracy of the tubular cutter is such

that a ring of .05 in. thickness and 5 in. diameter can be formed by cutting one disc out of another.

The surfaces of the disc are then roughly shaped to the required curves by a cup-shaped abrasive wheel, the annular end of which is used for grinding. The disc is held in a geometric clamp, and rapidly rotated about the axis of symmetry ; the axis of rotation can be brought into any required inclination to that of the abrasive wheel while the disc is in contact with the grinding edge. Hence with the axes parallel a plane surface could be produced, whilst perpendicular axes (if the machine could allow them) would produce a positive or negative curve of radius equal to that of the wheel according as to whether contact were made with the inner or outer edges of the abrasive wheel. Thus practically any curves from moderate radii upwards can be easily produced by one or two machines.

Polishing machines have also been developed along original lines. It was considered undesirable to retain the older practice of giving a practically linear motion either to the tool or work while the other rotated, as the starting and stopping of one member at the ends of its stroke are liable to cause malformation through inertia. Supposing the work to rotate on a vertical axis, the tool is given a motion by a pin attached to a crank. The shaft of the latter is directed to the centre of curvature of the work and is kept in continuous rotation ; thus the motion of the tool is continuous.

During the polishing process, the surfaces of the polisher and the glass are periodically supplied with rouge and water. When this medium has almost worked out or dried there is much greater resistance to the relative motion, and a squeak may be heard. An automatic squirt is used at Leicester ; this is brought into operation when the torque in the vertical spindle exceeds a certain limit, and it thus supplies the polishing medium as soon as it is required.

A word must also be added as to the edging process, which is also carried out by the aid of bonded abrasive wheels. The lens is mounted and centred with cement on a special cylindrical chuck mounted on a truly cylindrical shaft. In the edging machine this shaft rotates in V bearings. The standard of centring is a very high one ; it is especially necessary in photographic lenses of large aperture.

NON-SPHERICAL SURFACES.

The strict requirements as to the uniformity of optical path in a lens system naturally places the greatest responsibility, not only on the smoothness of individual parts of the lenses, but on their general shape also. The great regularity of form can only be obtained by more or less automatic methods, giving motions such as occur between the surface being produced and the correspondingly curved grinding or polishing tool. When there is a constant and practically a periodic change between the parts of the surfaces in contact, any excrescences in either will tend to disappear ; but it is only two spherical

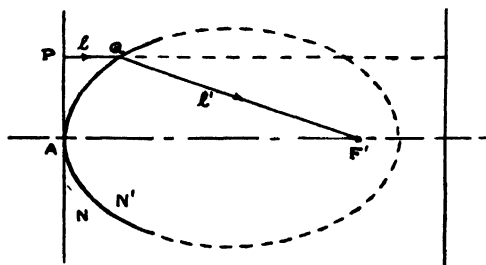


FIG. 7. Refraction at an ellipsoidal surface.

or plane surfaces which will exactly fit each other in any relative position. Hence the great importance and predominance of spherical surfaces in optical instruments.

The first great departure from the use of spherical surfaces has been in the making of spectacles. First of all came the employment of cylindrical surfaces. The cylindrical form necessary in the grinding or polishing tool restricts its general freedom of motion to a rotation about one axis combined with a corresponding movement of translation parallel to that axis. Later came the toric lens, in which the demand for the simultaneous correction of axial visual astigmatism and the removal of the astigmatism of oblique pencils calls for surfaces in which the curvature varies with the meridian. In this case the relative motion of polisher and surface is even more restricted, but in the case of spectacle lenses the eye really uses only a very small part at a time, compared with the whole area of the lens; hence the requirements for the over-all accuracy of figure are not nearly so exacting as in the case of other instruments, and as a matter of fact the non-spherical surface lenses are found to be very "sketchy" affairs when tested by rigorous standards.

Let us examine the type of surface necessary to bring a set of parallel rays to a perfect focus at one refraction. Fig. 7 shows the surface, and the trace of an incident plane wave PA . In the general case the optical path along any such track as PQF^1 must be constant; if N and N^1 are the refractive indices, then

$$Nl + N^1l^1 = N^1L^1,$$

where $PQ = l$, $QF^1 = l^1$, and $AF^1 = L^1$. This may be written

$$l^1 = \frac{N^1L^1 - Nl}{N^1} = \frac{N}{N^1} \left(\frac{L^1N^1}{N} - l \right).$$

This equation tells us that the length l^1 bears a constant ratio to the horizontal distance of the point Q from a line parallel to AP , and at a distance L^1N^1/N from it. This property is a definition of an ellipse, and it will be seen that the disturbances will meet in uniform phase on arrival at the further focus F^1 of the ellipse. If we desire to obtain the image in air it is easy to see that the use of a spherical refracting glass-air surface with its centre at F^1 will preserve the equality of optical paths. Otherwise the well-known properties of the pairs

of aplanatic points of a spherical surface may be employed for finding an alternative last surface which will produce zero path differences.

The elliptical front surface was calculated for the homocentric refraction of incident parallel rays ; if the object point lies at a finite distance the required curve is then of the fourth degree (a Cartesian oval, so called because the surfaces were worked out by Descartes). In recent years there has been a great revival of interest in the possibility of using accurate aspherical surfaces



FIG. 8. Removal of glass to form non-spherical surface.

in instrument work, beyond the familiar use of "figured" surfaces in telescopic and photographic objectives, and astronomical reflectors. In Fig. 8 let cc^1 represent a section of a required non-spherical surface and ss^1 the osculating circle which has the same curvature at the central part. To produce the correct figure a depth of glass must be removed, relatively to the sphere, which increases with the radius of the zone accurately in accordance with some law which will usually be expressed by an equation at least of the fourth degree. Can this be done automatically? So far it has not been achieved on large surfaces.

In grinding large parabolic mirrors for astronomical work the surface is first ground spherical ; the figuring is done during polishing, the amount of glass removed from different zones can be varied by the partial cutting away of the pitch polisher or by alteration of the amplitude of the movement of the polishing tool. The process has carefully to be controlled by a frequent resort to the Foucault knife-edge test, which can be used to locate the foci of the zones.

Figuring of the surfaces is also very necessary in making large refractors ; pads or ring polishers are employed for the local removal of glass, the process being controlled by observation of a star image and the appearance near the focus.

LARGE TELESCOPES.

Let us leave the general question for a moment to see something of the making of large telescopes. A large 40 in. reflector for the Russian observatory at Simeis has recently been made in this country for the Russian Government by Sir Howard Grubb, Parsons & Co., of Newcastle-on-Tyne. A disc of this size weighs five or six hundredweight, and the manufacture of the glass and its annealing is no small task. This disc was produced by the Parsons Optical Glass Co. of Derby.



FIG. 9. Giant telescopes in the course of construction. The 40"-mirror is 8" thick.
Below is seen the polishing tool.

(From Sir Howard Grubb, Parsons & Co.)

By the kindness of Sir Howard Grubb, Parsons & Co., I am able to exhibit several slides showing some of the operations in progress in the workshops. Fig. 9 shows the 40 in. reflector in course of figuring. Suitable tackle has to be provided for lifting the discs, and the arrangement of the shops includes a testing room over the polishing shop; thus the mirror can be tested by the Foucault knife-edge test while still on the machine. In one picture two large glass discs, made by the Parsons Optical Glass Co. for a 41 in. refractor, are seen. When this telescope is completed it will have the largest aperture of any telescope in the world. The record is at present held by the "Yerkes" O.G., which has a diameter of 40 in.

It is interesting to learn that the Simeis reflector has been tested by the Hartmann method (briefly described at the beginning of this lecture). The ascertained accuracy of the figure is within one-tenth of a wave-length of light. According to a criterion due to Hartmann the mirror is classified as "exceedingly good"; although by no means a very large mirror it is, for its size, one of the best in existence, and an achievement of which the firm may be justly proud. Other recent productions of the same firm include a 26 in. refractor for Johannesburg.

PRACTICAL EMPLOYMENT OF SMALL NON-SPHERICAL SURFACES.

The analytical theory of surfaces free from spherical observation has been developed over a long period from the time of Descartes (1637) to recent years. Linneman gave in 1905 an account of the theory of aplanatic lenses in which two non-spherical surfaces are used. Semi-aplanatic lenses have been produced commercially by Messrs. Zeiss in which one surface only is non-spherical. I am exhibiting specimens of these lenses in the present lecture by the courtesy of Messrs. Zeiss. Nevertheless, non-spherical lenses are so difficult to make accurately that they are not yet in general use in instruments.

On the other hand, they are finding a sphere of great utility in high-power spectacle lenses. In removing the astigmatism of oblique pencils it is well known that the effective "stop" or diaphragm should, on account of the rotation of the eye, be considered to be located at the centre of the eye-ball. Allowing for a space of 12 mm. between cornea and lens, and a distance of 13 mm. between the cornea and the point of rotation, the correct distance to assume for the "stop" is 25 mm. An analytical expression for the oblique astigmatism of oblique pencils then allows of the formation of an expression giving the curvature of the front surface of a thin lens, of given power, necessary to correct the oblique astigmatism. Real solutions for such an equation can be only found for powers between about 7.5 D and -25 D. Gullstrand therefore suggested that non-spherical surfaces might be employed for cases when powers of perhaps 11 D are required after operation for cataract. Lenses of this type (Kratall lenses) have been calculated by M. von Rohr* (1908) and made by Messrs. Zeiss. According to Henker, the deviation with respect to a spherical surface at the rim of the lens having a primary radius of 140 mm. does not exceed sixteen microns.

A further useful application of non-spherical surfaces is exemplified in various forms of dark ground condenser for microscopes. The most usual form is the paraboloid. The cardioid, proposed by Siedentopf, is not actually used in Messrs. Zeiss' instruments, but is sufficiently represented, in the comparatively small zone employed, by a spherical surface.

Is the effort automatically to produce non-spherical curves worth while, especially in view of Bessemer's costly and fruitless efforts? Conrady has recently shown that the main practical advantage is that of independent control over one aberration; for example, spherical aberration can be eliminated by the form of one surface; the other degrees of freedom of the lens system, the other radii, glasses, and thicknesses, etc., will then possibly allow of the removal of other aberrations in a more convenient manner. There can be no expectation, however, of obtaining high perfection by short cuts of this kind, for the main types of aberration, including the aberrations of oblique pencils, still arise in general, and must be dealt with. Furthermore, unless the

* *Die Brille als optisches Instrument*, M. von Rohr, 1921.

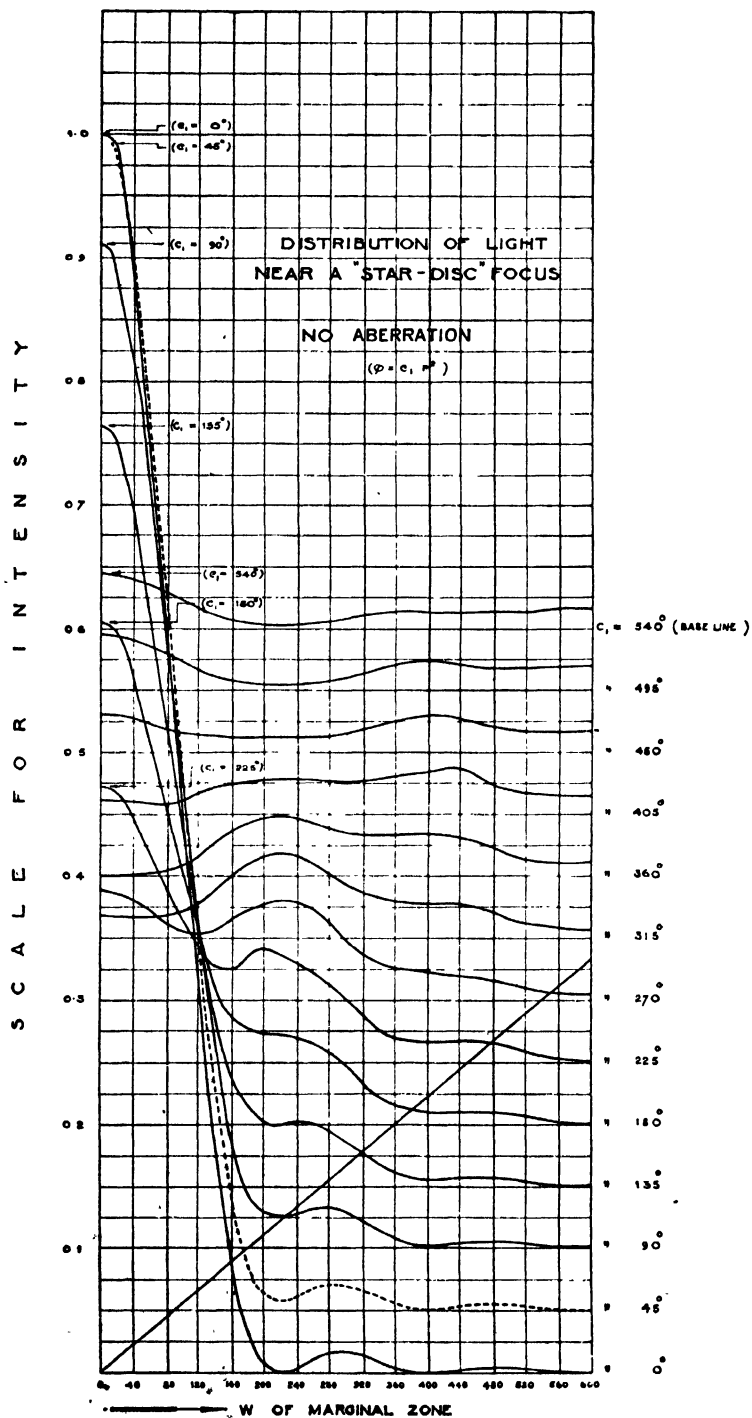


FIG. 10.

accuracy of the non-spherical surfaces can be made to conform to the requirements of the Rayleigh limit over the whole useful aperture, they would be worse than useless in many cases.

WHAT IS AN OPTICAL IMAGE ?

The question heading this section is by no means easy to answer, because the nature of light itself is not thoroughly understood. It is known, however, that the distribution of energy in the neighbourhood of an image can be successfully calculated if the simplest conditions are assumed, namely, a "star" image, and homogeneous light represented by a simple harmonic wave train. The enquiry may then be extended to more complex conditions. The first calculation of this type was made by G. B. Airy* in 1834, who calculated the intensity at points near the point of greatest concentration in the focal plane of a "perfect" lens. Rayleigh in England, and Strehl and others in Germany, have also given numerical results, but it is only within the last few years that the results of adequate calculations to find the distribution of light both in the focal plane and in neighbouring planes (firstly, in the absence of aberration, and secondly, in the presence of aberration of varying amounts) have been available. Such results are only obtained by very laborious numerical work, but they are very important because they give a basis for understanding the effect of definite amounts of aberration in lens systems, and thus they lead to the knowledge of the tolerance for aberration allowable under definite conditions. Practically every lens system constructed is the result of a compromise in which the residual aberrations are reduced below an objectionable limit. It is seldom or never that aberration can be completely removed; hence we cannot know too much about the effects of aberrations on the elementary image. The results to be discussed are mainly due to the staff and students of the Technical Optics Department at the Imperial College.

Figs. 10 and 11 show curves representing in a conventional way† the distribution of light near a "star" focus (monochromatic radiation) in the absence of spherical aberration and in the presence of a certain amount of primary spherical aberration respectively. (In the case of primary spherical aberration the successive circular zones surrounding the axis of the lens system have foci which are displaced from the focus of the central zone by amounts proportional to the square of the zonal radius.)

Looking first at Fig. 10, the base for each curve is taken one step higher in consecutive cases; the value of c_1 , given on the right against successive base lines, is practically proportional to the linear change of focus, and represents in degrees the relative change of phase,‡ introduced by the change of focus,

* *Camb. Phil. Trans.* 5 (1834) 238.

† *L. C. Martin. Trans. Opt. Soc.* 27 (1926) 249.

‡ If A be the diameter of the lens, and f the focal length, δf the axial change of focus, and λ the wave-length, then

$$c_1 = \frac{360^\circ}{\lambda} \cdot \frac{\delta f}{8} \left(\frac{A}{f} \right)^2$$

between disturbances arriving from the central zones and marginal zones respectively.

The curves for the case of spherical aberration are plotted much in the same way, and represent the state of affairs when the least outstanding phase difference between the disturbances arriving at the focus from the various parts of the lens amounts to 90° ; this minimum phase residual may be taken as a measure of the aberration.

The positions of the limiting rays are shown on the diagrams; it will be clear that the lateral scale of the diagrams has been disproportionately enlarged, but this is necessary to show the very fine structure of the interference and diffraction ring systems, which can only be seen in practice with the aid of extremely high magnification.

Taking Fig. 10, we see that it is possible to go to $c = 90^\circ$ before the central intensity falls to 0.8 of the maximum (unity); the first dark ring, which is so marked at the best focus, has, however, filled with light. There would be therefore at this point a definite falling off in the definition of a complex image, which we can regard as the resultant of an indefinitely great number of elementary images with varying intensities. The proper contrast in the complex image will be only secured by conditions in which the maximum energy enters the central condensation in each elementary image.

When spherical aberration is present, the effects on the two sides of the focus are now dissimilar, instead of the complete similarity characteristic of the absence of aberration, but there is one focus where an image resembling the Airy disc is found, although the central intensity is diminished. We also find the remarkable result that at other foci we may even find concentrations smaller than the Airy disc. It can be shown that under some conditions this may lead to the resolution of finer detail, although at the expense of contrast. Hence it appears that the mere resolution of detail is not an adequate guide to the estimation of the optical performance of a lens system. A full discussion of these curves would take too long, but there is one other result too important to be ignored.

In the diagram illustrating the results of spherical aberration, two "rays" have been shown, of which the intersection marks the limits of the geometrical "disc of least confusion" through which the ray tracks must all pass. This is found to be twice as large as the actual effective greatest concentration of light, which the integrations show to be found half-way between the paraxial and marginal foci, whereas the "least confusion" disc is found at three-quarters of this distance measured from the paraxial focus. There is evidently a considerable discrepancy in size and place between the geometrical disc of least confusion, usually interpreted as the best image by geometrical theory, and the actual physical focus. Such discrepancies are even more marked in other cases, especially in the presence of zonal spherical aberration, where the size of the actual physical focus in one case for which I have made integrations was shown to be less than one-eighth of the ray diffusion patch.

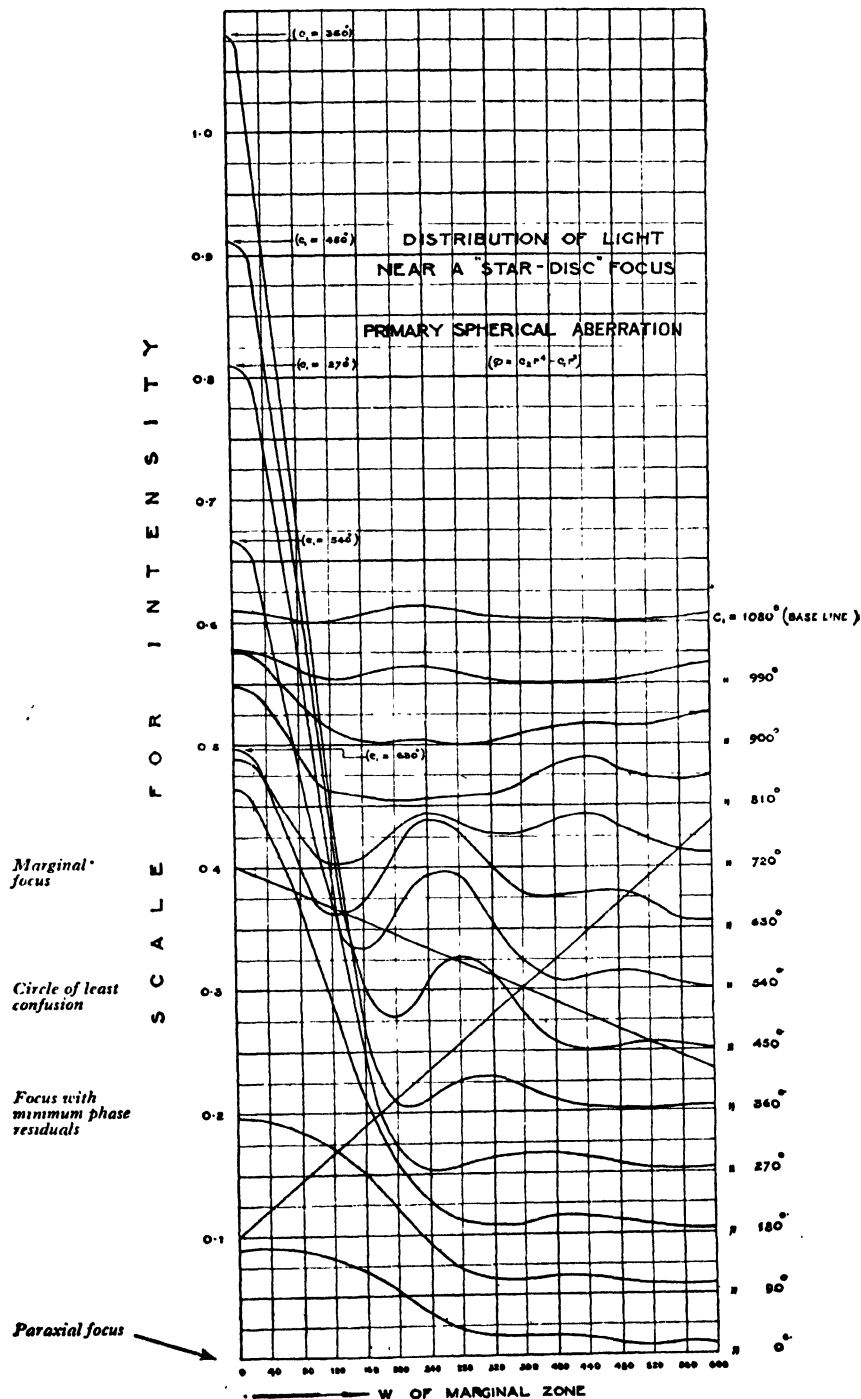


FIG. 11.

The case of the oblique aberration called "coma" shows an even more glaring discrepancy between the geometrical patch and the actual physical result, and this is well illustrated in Fig. 12. The lines show the patch within which the geometrical rays must pass; they have a greater concentration towards the pointed end of the figure, but there is little or no resemblance to the actual coma disc, which was photographed by a microscope objective I specially designed* so as to exhibit exactly the amount of coma for which I had previously carried out an integration. Thus the result of theory was well confirmed in practice.

These investigations are concerned with comparatively small amounts of aberration, but it is just these which chiefly enter into consideration in perfecting the design of optical systems. We now have corresponding information concerning other cases of coma and astigmatism which have been worked out by Buxton† and Steward.‡

The effects of larger amounts of spherical aberration, such as those likely to be met with in certain photographic lenses, have also been studied experimentally at the Imperial College by Miss H. G. Conrady. She has shown that

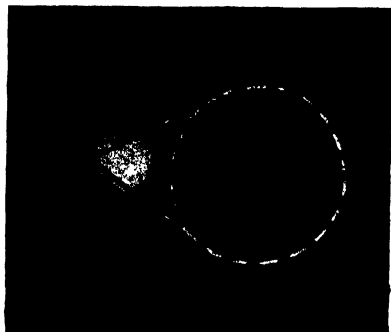


FIG. 12. The effect of coma, contrasting geometric theory with physical fact.

with increasingly large amounts of spherical aberration the "best focus" remains in an approximately fixed position with regard to the paraxial focus instead of following either the geometrical disc, or, for that matter, the focus half-way between the paraxial and marginal foci which is found to be effective with small amounts of primary spherical aberration. Other experiments have also been made on the effects of comparatively large amounts of coma.

INTERFERENCE METHODS IN ASTRONOMY.

It is an interesting experiment to follow up a suggestion made by Fizeau in 1868, and place a diaphragm containing two parallel rectangular slits just

* *Trans. Opt. Soc.* 24 (1922-23) 1.

† *Optical Convention Proceedings*, 1926. Part II, page 759.

‡ *Phil. Trans. Roy. Soc. A.* 225 (1925) 131.

behind the object-glass of a telescope, and then to examine the "image" when the instrument is directed towards a star or artificial star. For a variation we may use a single illuminated slit, with its length parallel to the diaphragm slits, for a source at some distance away. When sufficient magnification is used in the eye-piece a system of interference fringes is then visible. If the object-glass is optically good, a central bright fringe will be found in the axial position c where the disturbances from the slits A and B, Fig. 13, meet with equal optical paths, this being the place of the image formed by the unscreened

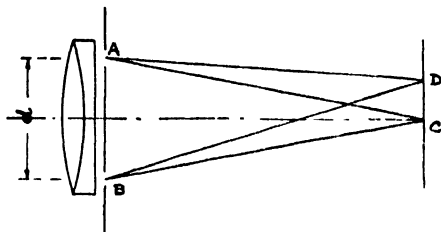


FIG. 13. Fizeau's experiment

lens. In the light of the discussions in the early part of this lecture, it will be evident that the position of this fringe should remain steady even if A or B should move. Any movement would imply an inequality of optical path for a disturbance from some part of the lens. The late Mr. S. D. Chalmers described a method of testing optical systems in this way. At some position D, where $BD - AD = \lambda/2$, there will be a dark fringe and so on; quite a number of fringes will be visible if monochromatic light is employed.

Suppose a second illuminated slit is mounted near the first and parallel to it; there will then be a second system of fringes in the focal plane of the telescope. The angular distance between the adjacent bright and dark fringes, of one system, in the focal plane, taken from the posterior nodal point of the O.G. is $\lambda/2d$, where d is the distance between the slits in the diaphragm. Hence, when the distance between the two object slits is such as to subtend just this angle, or an odd multiple of it, at the *anterior* nodal point, the bright fringes of one system will fall on the dark fringes of the other; thus they will tend mutually to extinguish all contrast. A similar extinction can be observed if one slit only is used and gradually widened, or even if an illuminated circular aperture forming the object is gradually increased in diameter; in the latter case the fringes become indistinct owing to the superposition of fringe systems from the series of elementary parallel slits into which we can conceive the circular aperture to be divided. The fringes cease to be visible when the angle subtended by the diameter of the circle is $1.22 \lambda/d$. If now the illuminated circular aperture is replaced by a star, it will be seen that the possibility of obtaining a disappearance of the fringes (and therefore incidentally a measure of the

stellar angular diameter) depends on the possibility of increasing d . With an O.G. or mirror of 100 in. diameter the smallest stellar disc, with which a disappearance of the fringe could be observed, is 0.05 seconds of arc.

In order to get over the difficulty of the employment of the very large lenses or mirrors which would be necessary to get the effect with smaller star discs, Michelson suggested an artificial extension of the aperture by the device shown in Fig. 14. The end of the reflecting telescope carries a slide at right angles to the axis, on which the four mirrors, M_1 , M_2 , M_3 , M_4 are mounted. M_1 and M_4 reflect the light from a star towards the axis, while M_2 and M_3 render the beams again parallel, when they can be brought to a focus E by the ordinary reflecting system of the telescope. The diagram shows the attachment to the 100 in. Hooker telescope at Mt. Wilson.

Under these circumstances, interference fringes can, in general, be observed at the focus with a magnification of 1,500 to 3,000 diameters. Although Michelson's preliminary experiments with simple apparatus were carried out in 1891, various causes delayed the work, and it was not until 13th December, 1920, that an observation on the bright star Betelgeuse showed the fringes

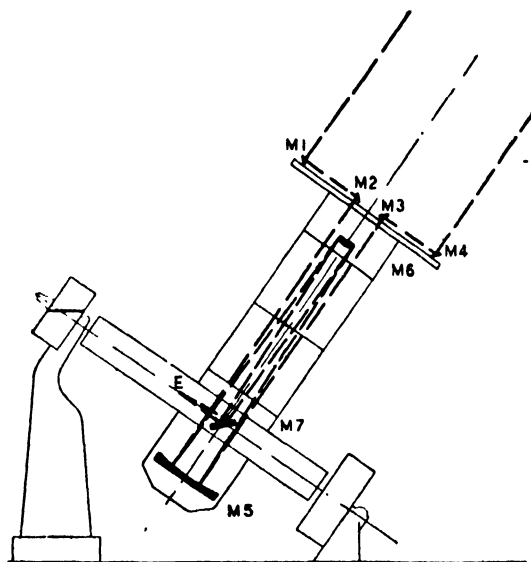


FIG. 14. Diagram showing the interferometer attachment to the 100" Hooker Telescope, Mount Wilson.

to disappear when the mirrors were ten feet apart, thus pointing to an angular diameter of this star of 0.47 seconds. As the distance of the star is approximately known from observations of parallax, it is found that the diameter of the star is almost as large as the diameter of the orbit of Mars. This measurement is undoubtedly one of the greatest achievements of optics. Many other stars have been "measured" since 1920.

In the present lecture we began by developing the idea of "optical path" in order to understand some of the vital problems which must be faced in any optical progress. The perfection and form of optical surfaces are coming increasingly under control, and a fuller knowledge of the physical meaning of aberrations leads to the formulation of tolerances allowable in various circumstances. The tremendous precision of modern optical methods is illustrated by Michelson's application of interference methods for the measurement of the angular diameter of stars. In the next lecture we shall see how measurements of equal precision are applied in technical optics for the perfecting of optical systems.

CORRESPONDENCE

BRITISH AND AMERICAN PRACTICE IN THE WORKING OF HOT AND COLD METALS.

In my paper on the above subject *Journal* No. 3879, page 448. there is a mistake in my calculations regarding the average force of blow of a drop hammer ; the figure 35 tons should be 336 tons, and 280 tons should be 2,690 tons.

Whilst these corrections are big ones they do not greatly affect the paper as there are many factors that govern the final pressures developed which can only be assumed.

F. W. SPENCER.

ENGLISH RAILWAYS.

I should like to be permitted to express my gratitude for the valuable information afforded to readers of the *Journal* by Professor Dalby in his paper on "English Railways," but I beg to suggest that the observation at p.887 that "the end of the 18th century (in 1799) found the pack horse the main carrier of goods on the ill-kept roads of England" may need reconsideration.

In a paper contributed to *Notes and Queries* (vol. Jan-June 1921 at pages 61, 84 and 102) on "London Coaching and Carriers Inns in 1732" I showed that considerable transport facilities radiating from the metropolis, existed even at that date. I cite here four examples only : carriers started every Saturday from the "Bell" in Wood Street for Taunton ; every Monday from the "Bell" in Friday Street for Truro ; every Saturday from the "Blossoms Inn" in Lawrence Lane, Cheapside, for Chester ; and every Tuesday from the "Bear" in Basinghall Street for York. For shorter distances they were far more frequent.

Doubtless pack horses were still used for carrying merchandise from provincial towns to surrounding villages.

J. PAUL DE CASTRO

NOTES ON BOOKS.

THE ARCHITECTURE OF ANCIENT GREECE. By William J. Anderson and R. Phené Spiers, revised by W. B. Dinsmoor. London: B. T. Batsford, Ltd. 21s. net.

Since the appearance of the first edition of this book archæologists have made discoveries, in Crete and elsewhere, which have shed new light on the origins of Greek architecture. But, as we read at the end of the first chapter, *Ægean* architecture, though earlier in date, was a parallel development, and not the immediate source of Greek architecture; the true fountain head lay rather in the earlier northern home from which came the successive *Ægean* invaders of Greece.

The Dorian invasion happened at the beginning of the twelfth century B.C. The Dorians mixed with the Achæans, whose civilisation they had not so much destroyed as interrupted, and later also absorbed the Ionians who had fled before them to Attica and Asia Minor, and whom unappeased land-hunger impelled them to follow.

Was the Doric column more akin to the fluted Egyptian column, five or six diameters high, or to the wooden column of the *Ægean* period? The earliest Doric columns were very thick in relation to their height, and it seems likely "that the well-known timidity of the Greeks in stone construction would be enough to account for the sudden thickening of the proportions when translating from a prototype hitherto of wood."

The Ionic column was, of course, not a development of the Doric, but an independent and more or less contemporaneous growth. Here, however, Egyptian influence must be allowed. "Egyptian decorative capitals frequently represented the papyrus superposed on the fleur-de-lys; and it is this type, with the calyx of the lily conventionalised in triangular form, and the papyrus stiffened and reduced to form a palmette, that we must regard as the source of the Proto-Ionic capital." Fig. 17 shows a Proto-Ionic capital from Neandria, which illustrates the point. This capital has the girdle of overhanging leaves which was eliminated shortly afterwards.

Plentiful photographs, as well as reproductions of sketches of reconstructed temples, enable the reader to compare and to form impressions of the two styles. Plate XXII shows the temple of Poseidon at Paestum, as it stands to-day, in all its unvarnished Doric magnificence; while on Plate I. we have Henderson's restoration of the later temple of Artemis at Ephesus, with its slender columns and ornate pedestals. Pliny described this temple, which was one of the seven wonders of the ancient world. Time was unkind to it; and an important part of all that is left of it can be seen at the British Museum.

The Corinthian order is said by Vitruvius to have been the invention of Callimachus, one of the talented members of the Periclean circle. The earliest known example of a Corinthian capital is from the temple of Apollo Epicurius at Bassae in Arcadia, built by Ictinius, the architect of the Parthenon; but the first Corinthian column found to have been used externally was in the choragic monument of Lysicrates at Athens.

A Corinthian temple destined to be of the greatest importance was begun in 174 B.C. near Athens, but never completed. Sulla, after he had taken Athens in 86 B.C., transported some of the columns to Rome, and there they exercised a profound influence on the development of the Roman Corinthian style.

A useful and most interesting book, with an excellent table giving the approximate dates and chief dimensions and proportions of the Greek temples.

P. B.

JOURNAL OF THE ROYAL SOCIETY OF ARTS

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FRIDAY, AUGUST 26th, 1927.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C.(2.)

NOTICES.

THOMAS GRAY MEMORIAL TRUST.

PRIZES FOR THE IMPROVEMENT AND ENCOURAGEMENT OF NAVIGATION.

Under the will of the late Thomas L. Gray, the Royal Society of Arts has been appointed residuary legatee of his estate for the purpose of founding a memorial to his father, the late Thomas Gray, C.B., who was for many years Assistant Secretary to the Board of Trade (Marine Department).

The objects of the Trust are "The advancement of the Science of Navigation and the scientific and educational interests of the British Mercantile Marine."

The Council now offer the following Prizes :—

- (i) A Prize of £100 to any person who may bring to their notice a valuable improvement in the Science or Practice of Navigation proposed or invented by himself in the years 1927 and 1928.

In the event of more than one such improvement being approved, the Council reserve the right of dividing the amount into two or more prizes at their discretion.

Competitors must forward their proofs of claim on or before December 31st, 1928, to the Secretary, Royal Society of Arts, John Street, Adelphi, W.C.2.

- (ii) A Prize of £50 for an essay on the following subject :—

"The Practice of Navigation in the Mercantile Marine."

The essay must be based on the actual methods used by the writer during his career, with special reference to the instruments used as aids to navigation, and the effect of stowage of cargo on the steering, speed and safety of the vessel.

Competitors must send in their essays not later than December 31st, 1928, to the Secretary, Royal Society of Arts, at the above address.

The essays must be typed or clearly written. They must be sent in under a motto, accompanied by a sealed envelope enclosing the author's name.

The Judges will be appointed by the Council.

The Council reserve the right of withholding the Prize or of awarding a smaller Prize or Prizes, if in the opinion of the Judges no suitable essay is submitted.

The Council also reserve an option on the copyright of the successful essay.

G. K. MENZIES,
Secretary.

EXHIBITION OF INDUSTRIAL DESIGNS.

The exhibition of the work selected by the judges from that submitted at the Society's Annual Competition of Industrial Designs is now being held in the Indian Pavilion of the Imperial Institute, South Kensington, and will remain open every week-day until August 31st, from 10 a.m. to 5 p.m. (Sundays 2.30 to 6 p.m.)

The Exhibition is open free of charge; no tickets are required.

A Bureau of Information has been established at the Royal Society of Arts in connexion with the competition, for the registration of the names and addresses of exhibitors who desire to obtain employment as designers. These lists are at the service of manufacturers in search of designers.

PROCEEDINGS OF THE SOCIETY.

CANTOR LECTURES

RECENT PROGRESS IN OPTICS.

By L. C. MARTIN, D.Sc., A.R.C.S.,

Assistant Professor, Technical Optics Department, Imperial College of Science and Technology.

LECTURE III.—*Delivered January 31st, 1927.*

It is usually somewhat surprising for a novice in optics when he consults for the first time a glass-maker's catalogue of optical glasses. The wide range of types of glass offered is a revelation to anybody whose knowledge does not go beyond the "crown" and "flint" of the physics text books. It is possible, however, to understand generally some of the reasons for this multiplicity of types. Consider such a simple lens as a cemented telescope object-glass. We require that it shall be of a certain focal length and also "achromatic," perhaps in the sense that it brings rays of two given wave-lengths (often the "C" and "F" wave-lengths of the solar spectrum) to

the same focus. These requirements practically determine the total powers of the "crown" and "flint" lenses which are made from two glasses which we could choose. If the lenses are to be cemented, the main things still left to determine are the shape of the front surface and the thicknesses; the curvature of the front surface, which determines the other curves if the "powers" are given, is the most significant feature. We can then choose this curve to abolish spherical aberration, when the outstanding defects which remain will be "coma" (an aberration of the oblique pencils), and the so-called secondary spectrum. This last aberration is measured by the extent to which the foci for the other wave-lengths fail to coincide with that of the "C" and "F" wave-lengths (in the red and blue-green) which were united by the construction of the lens. These residual aberrations can only be overcome satisfactorily by choosing suitable types of glass. Thus the secondary spectrum can be considerably reduced by using a glass known as "telescope flint" for the "negative" component in combination with a "hard crown" positive, although it is then necessary to use much deeper curves. We can secure a lens with only a small degree of coma by choosing a "medium barium crown" to unite with a dense flint. From this example it will be readily gathered that the nature of the glass is a highly important matter. Thus during the war, an important lens for aerial photography was able to be successfully made because a glass known as "extra light flint," which combines a fairly low refractive index with a high dispersion, was successfully produced in this country by Messrs. Chance Bros. and Co., Ltd. The same firm produced, also for this purpose, two dense barium crown glasses which have high refractive indices and relatively low dispersions.

Very often in designing a complex system a computer will start out with a trial set of glasses for his components. He may find large aberrations arising, perhaps, at a cemented contact surface, which are not easy to abolish. By substituting another glass in one lens it is often possible to reduce the curvature of the contact face without altering the system very greatly, and thus to gain control over the aberration in a manner otherwise impossible. In another case a computer will design his system to abolish spherical aberration, making only rough provision for achromatism. He will have fixed the absolute refractive index of his glasses, and then when the system is practically complete he may work out the dispersions which the glasses should have in order to give proper achromatism. Now Fig. 27 represents the glasses available from Messrs. Chance Bros. and Co., Ltd., of Birmingham, in which the refractive index is plotted against the "V" value which depends on the dispersion. If our computer had one glass of refractive index about 1.515 he would have a range of possible V values from 64 to 53 amongst different glasses, ranging from "boro-silicate crowns" through "hard crowns" and "zinc crowns," for the art of the glass maker is so far advanced that he can produce to order many types intermediate between those of the catalogue; it is by no means

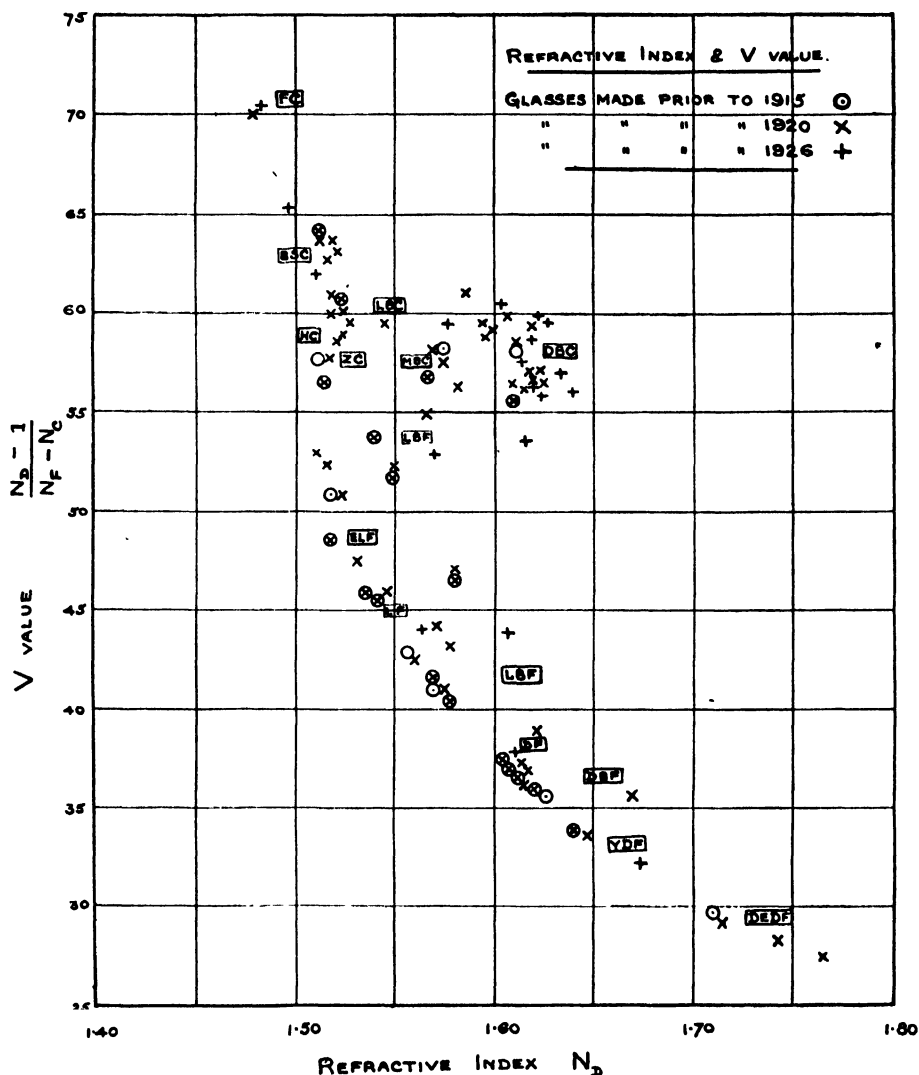


FIG. 27. Types of optical glass made by Messrs. Chance Bros. and Co., Ltd.

unknown for an optician to call for a particular glass if he cannot find a suitable one. Messrs. Chance Bros. made a "medium barium crown" specially to the order of Messrs. Dallmeyer for the Dallon Telephoto lens. Fig. 27 is self-explanatory, it shows the pre-war glasses by circles, those from 1915 to 1920 by $\times$ and those from 1920 to 1926 by $+$.

Two other firms, the Parsons Optical Glass Company, and Messrs. Barr and Stroud, Ltd., have undertaken the manufacture of optical glass. The first mentioned has just issued a catalogue of 120 types of glass which covers

most of the modern types aiming at better possibilities in colour correction. In addition to the specification of the refractive indices of their glasses for the usual wave length, they have added figures for the refractive indices for five new lines in the visible spectrum; this certainly furnishes a more complete picture of the performance of the glass as regards dispersion. Peddle's systematic researches* on the production of various types of optical glass form a most interesting chapter in our war-time scientific efforts.

This refinement of specification of refractive indices legitimately raises the question, "What are the tolerances for chromatic aberration under various circumstances?" As a matter of fact, very little systematic study of such a question has ever been undertaken. The present practice in chromatic correction is very empirical and is mainly the result of experience and custom; the matter is not uninfluenced by the fact that certain spectrum lines, such as the C and F lines mentioned above, are easy to produce for measuring purposes. The whole question is partly a physiological one. Already we have begun to study this in the Technical Optics Department,† and it is the kind of fundamental research in which a teaching department ought to be engaged.

Messrs. Barr and Stroud also record great improvement in their glass; which is mainly being used for their own instruments. They claim that the transparency of their glass has been improved by 50 per cent. during the past few years, a result not accomplished without great efforts. The standard of transparency of British optical glasses has always been a high one, and Messrs. Chance Bros. have claimed that their pre-war glass led the world in this respect.

Thus at the present time we have progressed so far from the conditions of 1914, when we imported 60 per cent. of our optical glass from Germany and 30 per cent. from France, that our own factories can supply any reasonable requirement. In addition there are now several new types obtainable in this country which are not made elsewhere. The greatest credit is reflected upon the firms concerned, who in the height of war-pressure (1918) were producing nearly 9 tons of optical glass per month.

One question which has attracted considerable attention is the subject of coloured glass, which is required for many industrial, military and scientific purposes. The production of successive meltings conforming exactly to prescribed "wave-length and absorption" relations is a very difficult matter and the attention of the British Scientific Instrument Research Association has been directed to this question, especially as regards production of a "neutral" glass for use in sextant shades. In previous times these "neutral" glasses found in various instruments had very often a marked

* *Journal of Soc. of Glass Technology*, Vol. 4.

† A paper on this subject by R. G. Kingslake, has now been read before the Optical Society.

residual hue, and, moreover, they differed widely amongst themselves. It is now possible, however, to produce a good neutral glass of standard absorption and there is no doubt that before long other types of glass will be standardized in an equally satisfactory way, although those glasses, such as selenium ruby glass, which produce their colour through the presence of ultra-microscopic particles of uniform size, and not on a coloured silicate, present difficult problems.

Many of the problems in glass manufacture, such as the production of homogenous glass free from strain, have only been solved by close attention to every step in the manufacturing process. The method of stirring, the period of melting, the furnace temperature, and so on, are all of importance; no question, however, is of more moment than that of annealing. F. Twyman* treated the question as a viscosity problem, and showed that the mobility of most glasses through the critical range, from 400° C. to 800° C., doubles for each 8° rise in temperature. He studied the relief of stress in hot glass by examination in polarized light, and his results agreed with Maxwell's tentative suggestion that the rate of decrease of stress is proportional to the stress itself. Adams and Williamson (America) corrected these results in detail, but confirmed the main trend of Twyman's physical results. The practical results of the British research were to determine the particular limited ranges of temperature for various glasses over which the cooling after melting should take place very slowly, and this knowledge of the proper "annealing temperature" enabled the whole cooling and annealing process, which had sometimes taken perhaps fourteen days to carry out, to be shortened to three and a half days.

It is not long ago since the majority of lenses were roughly shaped by grinding down a suitable flat disc of the right diameter on a large rough iron tool with emery. We have seen how one firm has introduced, for the best type of work, a method of grinding with an abrasive wheel. In less particular work it is nowadays increasingly the practice for opticians to mould the glass into the approximate form desired or to purchase such moulded blanks from the glass maker. Thus in the making of spectacles sheet glass can be cut into pieces of the right approximate weight; such a cutting avoids the bubbles and striae, previously marked in the sheet. The sorted pieces are then heated in a furnace till soft, patted into an approximate circular shape with tongs, and finally moulded in hot dies, during which operation the blanks harden sufficiently to retain their shape. They have to be annealed very carefully at a temperature sufficient to allow of the relief of internal stress, but not so high as to allow the surfaces to lose their figure.

BI-FOCAL SPECTACLE LENSES :

The proper selection of glass and the annealing process are of great importance in the manufacture of modern types of fused bi-focal spectacles. We shall

* *Jour. Soc. Glass Technology*-1 (1917), 61.

have no time to go into the whole question, but it may be illustrated by the steps in the production of the so-called invisible bi-focal lenses. The bi-focal is fitted, say, with a reading segment in a variety of ways; the segment may be cemented, or a portion of the surface of the one-piece lens may be given a different curvature, by no means an easy matter. Yet another method is to "fuse in" a lenticular segment of denser glass before the grinding and polishing of the outer surfaces to uniform curves. This results in a lens of practically uniform outer appearance, and allows of the production of a variety of shapes in the reading portion, as illustrated by Fig. 28.

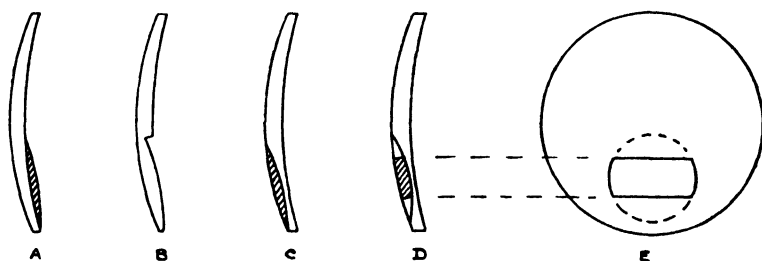


FIG. 28- FORMS OF BI-FOCAL SPECTACLE LENS

- (A) CEMENTED TYPE (C) FUSED TYPE
 (B) UNI-BIFO TYPE (D) FUSED TYPE WITH SECTIONAL READING SEGMENT
 (E) FRONT VIEW OF 'D'

The glass used in the reading segment must be denser, and a flint glass would be the first choice. A little thought will show that in the reading portion of the lens we should then possess a convex flint combined with a negative crown—exactly the reverse of the combination employed in an achromatic lens, and giving, therefore, an enhancement of "coloured edge" effects to images viewed with its aid. It is easy to show that in order to minimise the colour effects the dispersion of the glass for the reading segment should be as low as possible; hence a crown glass of high refractive index and low dispersion is employed, but its physical properties must be suitable for the required purpose of fusing into the main lens. It has been shown that glass surfaces can be made to fuse together without sensible distortion or flow by keeping them in contact at the right temperature. Hence the two faces to be fused are first optically polished to the correct curve and then raised to the required temperature while in contact in a suitable oven. When fusing is complete the temperature is lowered at the proper rate and the outer curves are ground and polished.

Experiments in the production of such fused glasses have been in progress since 1897. Successful specimens with flint reading segments were produced by Borsch in Paris in 1904, and such spectacles subsequently became well known as "Teleçic" glasses in Germany and, under the name "Kryptok,"

in America and England. The presence of imperfections in barium crown glasses for a long time prevented their satisfactory employment for the reading segment, but a suitable glass of this type has been produced by Messrs. Chance Bros. in this country, and a series of entirely satisfactory fused bi-focals, giving a minimum of colour, are now made by the United Kingdom Optical Co., Ltd., under the name "Akro." Specimens of these are being exhibited.

RECENT PHOTOGRAPHIC LENSES.

We have already referred to the use of optical glasses in new photographic lenses. The past few years have witnessed the successful production of some very large aperture photographic lenses, and it may be of interest to see how one of these, made by Messrs. Taylor, Taylor and Hobson, Ltd., was evolved.

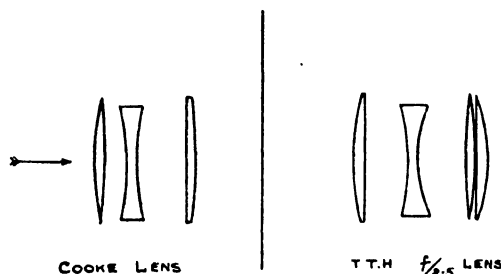


FIG. 29.

The original design of the Cooke lens is shown in Fig. 29. In the $F/3$ type, computation shows that a large amount of under-corrected spherical aberration, which has to be compensated by the negative lens, occurs on the last surface. In the ordinary design this sets a limit to the relative aperture, but the latter can be increased if the spherical aberration due to the last lens is diminished by separating it into two components, thereby lessening the over-correction required from the negative lens. It is well known also by optical designers that they can produce a comparatively large amount of deviation in a ray, at a relatively cheap price in aberration, by using glass of high refractive index. Therefore these alterations, together with other suitable modifications, were made to that type of the Cooke lens working at $F/3$, and the Taylor-Hobson $F/2.5$ Anastigmat resulted. The process is not quite so simple as the above description would lead one to infer, but necessitates many careful and systematic trials.

The same firm has also produced lenses working at $F/2$ and even one at $F/1.5$. The $F/2$ lens is said to give the widest anastigmatic field, 25° on each side of the axis, of any competing construction for lenses of this aperture. The $F/1.5$ gives good definition over a smaller field, 10° on each side of the axis, and is of a modified Petzval type.

Mr. Leslie Eveleigh, F.R.P.S., recently investigated the lenses used at Hollywood for cinematography, and found that British lenses, chiefly repre-

sented by Dallmeyer and Cooke lenses, hold pride of place. Messrs. Dallmeyer have produced the Pentac lens working at $F/2.9$, and another working at $F/1.9$, as examples of large aperture ratio lenses. By the courtesy of the firm I am exhibiting an $F/3.5$ Dalmac and an $F/2.9$ Pentac lens here this evening.

We have already commented on the defeat of achromatism known as the secondary spectrum. When photographic lenses have fairly short focal lengths the removal of the secondary spectrum is not a matter of primary importance for the ordinary purposes. Nevertheless, there are some lenses, those intended for use in the three-colour printing process, for which the highest achromatism is required, not only for the image point on the axis, but also for points in the field; in other words, images taken by red, green, and blue light must have the same size. This calls for "achromatism of the focal length" as well as of the focal point.

Such conditions have not, up to the present time, been fulfilled in lenses of the large aperture described above, and process lenses have therefore to work to smaller apertures $F/8$ to $F/16$. The sufficient attainment of the necessary freedom from colour and other aberrations is partly a matter of the successful choice of glass combinations; it is in such respects that the additional information given by the Parsons' Optical Glass Catalogue is likely to prove most useful. A number of our British firms are now making improved lenses of this "apochromatic" type, and Messrs. Ross, Ltd., and Messrs Taylor, Taylor and Hobson, Ltd., were exhibiting them at the Optical Convention.

In yet another branch of photographic optics, tele-photography, there have been considerable advances, for which reference may be made to papers read at the Convention by Lee and Booth. One notable achievement in this connection has been the reduction and practical abolition of the pincushion distortion which is usually present in telephoto lenses. This was done by deliberately making use of a large amount of astigmatic aberration arising at some of the intermediate surfaces, which is sufficient to correct the distortion; the astigmatism is neutralised and does not appear in the final image. This example shows well how an aberration, which by the approximate algebraic theory appears hopeless to correct, can in actual practice be got rid of.

DEPTH OF FOCUS.

The greatly increased aperture of some modern lenses has caused some little trouble to the not-too-careful amateur; it may therefore be well shortly to look into the question of "depth of focus."

Fig. 30 represents a lens forming an image I of an axial object O . It is supposed free from spherical aberration so that the optical paths OBI , OAI , OCI are all equal. The curve BAC is a part of a circle drawn with O as centre, and marks off equal distances from O . If the object point is displaced to

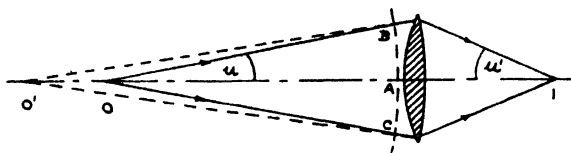


FIG. 30.

O' there will be a difference of optical path amongst disturbances arriving at I from O'; we can assess the difference of path as O'A-O'B, and this can be shown to be equal to $\frac{a^2}{8} \left(\frac{1}{O'A} - \frac{1}{OA} \right)$, where a is the aperture BC, if the angle BOA is small. Miss H. G. Conrady has recently investigated the depth of focus of photographic lenses of small aperture, and it has been found that the practical focal range is in practice largely dependent on the optical path differences of disturbances arriving in the image. Let $\pm k$ represent the allowable path difference; then if the distance OA is d , and d_1 and d_2 are the new object distances producing path differences of plus and minus k respectively, then

$$2k = \frac{a^2}{8} \left(\frac{1}{d_1} - \frac{1}{d_2} \right), \text{ and } \frac{1}{d_1} + \frac{1}{d_2} = \frac{2}{d}.$$

When d_1 and d_2 are not greatly different from d we find

$$d_2 - d_1 = 16k \frac{d^2}{a^2}.$$

Hence the depth of focus in the object space is, if the above assumptions be true, simply dependent on the square of the actual aperture of the lens opening, that is for lenses working at the same value of d . On the other hand consider the focal range in the image space; the angle u' of convergence of the marginal rays will be considerable; if f is the focal distance, the path difference introduced by an axial focal displacement δf will be approximately $\frac{\delta f}{f} \left(\frac{a}{f} \right)^2$. Hence if this may grow on the two sides of the focus to $\pm k$

respectively, the total focal range $\Delta f = 16k \left(\frac{f}{a} \right)^2 = 16k \times (\text{square of the}$

stop number). Hence the focal range, *i.e.*, the allowable inaccuracy in setting the focussing screen, will be roughly proportional to the square of the stop number. Let us now consider the action of two lenses of the same focal length, which will give pictures of the same size; one has an aperture ratio F/2 and the other has F/4. It is clear that the first must have an actual aperture roughly twice that of the second. Hence the depth of focus both in the object and image space of the F/2 lens will be approximately a quarter of the corresponding values for the F/4 lens of the same focal length.

If, on the other hand, we take two lenses of the same *actual* aperture they will have the same depth of focus in the object space. The F/2 lens will

now have only half the focal length of the F/4 lens, and consequently the former will produce pictures of half the linear dimensions of the latter. The depth of focus in the image space of the F/2 lens will be one quarter that of the F/4 lens, so that proportionately greater care will have to be taken in setting the plate. However, when the smaller image is enlarged ($\times 2$),

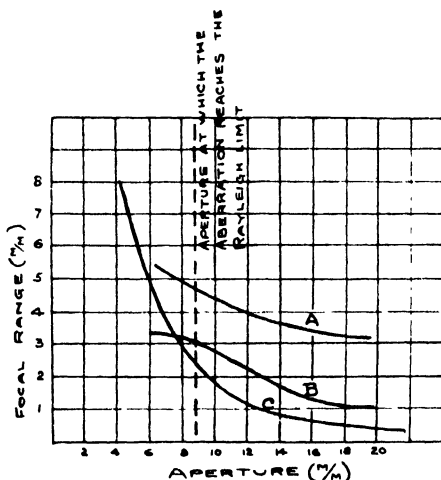


FIG. 31. { A. Focal range (extreme limit of fair definition).
 B. " " ("physical" " good ").
 C. " " by physical theory for perfect lens.

its depth of focus will be equal to that of the larger, and hence the big aperture lens will be just as satisfactory for landscape and general photography. With the F/2 lens, the divisions on the focussing scale, if one is provided, will only be about quarter of the size of those on the scale for the F/4 lens of the same diameter, so that an error in *judging distance* will not produce more serious results in the one case than in the other; on the other hand, any error in setting the scale will have far more serious consequences when the big aperture lens is employed.

There is some considerable confusion in the use of the term "depth of focus" at the present time. Would it not be well to restrict the use of this phrase to the object-space, and to employ the different term "focal range" for the image space. At any rate, some suitable distinguishing terms should be employed.

Some of Miss Conrady's actual results are shown in Fig. 31. In these experiments a small photographic lens was used at gradually increasing relative apertures, thus increasing the optical path differences in the disturbances arriving at the best focus. The range for a perfect aberration-free lens is calculated on the basis of $k = \pm \lambda/4$, where λ is the wave-length. The minimum focal range for the actual lens is given as the range over which no perceptible breaking down of the photographed image is apparent, and

the maximum range as the range beyond which the falling off of the quality of the image becomes very marked. When the aperture is relatively large there are large amounts of primary spherical aberration, which actually increases the focal range, and over half the diagram the focal range is proportional roughly to that of a perfect lens, though involving values of k which are three times as great even for the minimum focal range. This work was done with white light, so that it is possible to see that the conclusions based on considerations of homogenous light are greatly modified in actual practice. The conclusions will have to be modified, too, when lenses of extremely large aperture are brought into discussion. It would be very difficult indeed to forecast the results when such lenses are employed with white light, and further experiments are very desirable.

DEVELOPMENTS IN SURVEYING INSTRUMENTS.

We can only refer very briefly to the remarkable developments which have taken place in surveying instruments within the past few years. The size and weight of the theodolite has been greatly reduced without loss in accuracy, micrometer methods of circle reading being adopted in quite small instruments. The precision of setting of an optical sight is dependent largely on the resolving power of the system; thus if this is maintained there is no reason to fear inaccuracy through shortening the telescope. The use of internal focussing lenses permits of the employment of air-tight telescopes, and the same device brings about a reduction of the possibility of variable collimation with change of focus. All instruments are weather and dust proof to a far greater extent than formerly, and Messrs. E. R. Watts and Son, Ltd., have introduced a bubble level in which the length of the bubble remains constant with change of temperature. The device of circle reading from both sides in the same eyepiece, proposed in Germany about 1898, was taken up by Baalsrud in Sweden, Wild in Switzerland, and the firm of Casella in this country. One of Wild's systems is also used by Messrs. Zeiss, and their new theodolite is a most interesting, though complex, device, both vertical and horizontal circles being read in the same eyepiece. It is an instrument of great compactness and accuracy. Messrs. Casella have placed on the market an instrument built on much simpler lines, in which the vertical and horizontal circles are read with separated eyepieces, but both on the double-reading system.

The level is an instrument which has also shown great development. The Wye and Dumpy types have given place to instruments employing a simple "gradiometer screw" device by which the telescope and bubble tube are given small rotations in altitude. The only field adjustment is to secure parallelism between the bubble tangent and line of collimation of the telescope by some standard method. The bubble tube is then clamped to the telescope, and the bubble can be centred by the gradiometer screw for each shot. A typical example is the engineer's precise level of Messrs. Cooke, Troughton and Simms.

Levels of the Wild-Zeiss pattern capable of adjustment from one station have been developed; one of their most valuable features being the prism bubble-reader, which avoids parallax in bubble reading and saves marking the bubble tube. In some instruments recently produced in this country specially made and adjusted reversible bubbles allow of single station adjustment in two readings, the telescope and bubble tube being capable of rotation about an axis approximately coincident with the axis of symmetry of the former as in the Wild system; but in this case the direction of the optical sight is not reversed end for end. This throws a greater responsibility on the accuracy of construction of the instrument. The factor of speed in levelling operations is always a matter of importance. In recent times Messrs. E. R. Watts and Son, Ltd., have introduced a small level in which levelling screws are dispensed with; the instrument is mounted on a "three-point" support moving in a shallow spherical cup, and the small circular bubble can be centred by the use of an arm projecting downwards from the instrument. In another instrument, the "Auto-set" level, the rough levelling is obtained in a similar way. Provided the main bubble is within a certain range in its tube, the line in a prism reader is set to coincidence with the bubble end (which is one of the constant length variety). This setting automatically adjusts the collimation of the telescope with the aid of a tilting plate placed in the convergent light from the object glass. Thus there is no need to adjust the bubble tube in one or two steps and wait for the bubble to come to rest. Tests have shown this instrument to be accurate, and the time taken in "setting up and obtaining a shot" is about twenty seconds.

New forms of tacheometer have also been recently introduced, such as the "Jeffcott" of Messrs. Cooke Troughton and Simms, Ltd., and the Watts-Szepessy tacheometer of Messrs. E. R. Watts and Son, Ltd. These instruments permit the tacheometric determination of both height and distance.

PHOTOGRAMMETRY.

Reference must also be made to the developments in photographic surveying or photogrammetry, which call in the first place for high standards of precision in photographic apparatus. As in ordinary triangulation, the ascertainment of the bearings of a set of points from two known station points is necessary and in the photographic method these bearings are found from a pair of photographs taken under prescribed or determinable conditions.

By suitable optical methods, such photographic pairs can be made to give a stereoscopic reconstruction of the space image, and Thompson* and Conrady devised in 1908 a "stereo plotter" by means of which a map showing any points common to both photographs can be drawn point by point. This was an extension of the stereo-comparator† of Pulfrich.

* *Geograph. Journ.* 31 (1908), 534.

† *Z.f. Instrk.* 22 (1902), 65.

In von Orel's stereo-autograph* the movements of a pencil on the "map" record the apparent movements of a "wandering mark" in the space image, and thus allow contours directly to be mapped out. Wild's stereo-cartograph was a development of another idea for the same purpose. These latter instruments are arranged to deal with photographs taken from known ground stations, but not necessarily with parallel or truly horizontal camera axes.

The development of aerial photography has called for instruments capable of dealing with pairs of photographs taken from the air, in which the camera axes may have almost any relative angles; such instruments are exemplified by the auto-cartograph of Hegershoff† (developed by Heyde), and the stereo-planigraph‡ of Zeiss. These instruments are among the most ambitious and ingenious of optical productions, and will well repay a study of the various points of their construction.

A LARGE RANGE-FINDER.

Up till about six years ago the largest self-contained range-finders had base lengths not exceeding thirty feet, but the increasing accuracy of modern gunnery, and the tendency to begin actions at great ranges calls for increased precision in range-finding for defensive purposes.

If a range-finder of base length b is directed to a target at a distance R , the parallax angle α is given by b/R . Since, by differentiating, $dR = -R^2 d\alpha/b$ we see that the error, dR , in range corresponding to a given error $d\alpha$ in a determination of parallax is proportional to the square of the range. In the coincidence field, the vernier acuity of the practised eye is sometimes well within 6 seconds of arc; therefore when using a telescope system of magnification $\times 28$ the effective accuracy will be perhaps as small as one-fifth of a second. Assuming the roof-t. base, this gives an accuracy of one yard at 6,000 yards or $5^2 = 25$ yards at $5 \times 6,000 = 30,000$ yards.

The firm of Barr and Stroud has recently produced a range-finder with a base length of roof-t. Though the central optical system need not be greatly enlarged, the highest magnification used in the telescope system being $\times 28$, the diameter of the instrument (at the ends of which the reflectors are carried) must be small in proportion to the length, and the mounting of such a tube with the necessary freedom from flexure is a problem of some difficulty. It has been solved by the use of a system of pivoted cantilevers upon which the "tube" is carried in eight bearings. This mounting forms a rigid framework connecting two trucks running on a circular roller path 50ft. in diameter. It is a tribute to the efficacy of the instrument that the errors (estimated as parallax) found in an independent test did not exceed 0.3 seconds of arc in any case, the mean error being 0.15 sec.

* *Z.f. Instrk.* 41 (1921), 1

† *Geog. Jour.* 59 (1922), 4

‡ *Z.f. Instrk.* 43 (1923), 1

MECHANICAL DESIGN OF INSTRUMENTS.

The mechanical design of instruments is a subject too vast to be dealt with here, but its importance is very great ; very often the optical part of an instrument is quite subsidiary, as is the case in instruments like levels, theodolites and other forms of measuring instrument in which the mechanical construction is the main thing for consideration. In practically any instrument, taking the microscope, for example, the proper functioning of the optical parts is impossible unless their mounting and moving is successfully carried out by the mechanical design.

While the present construction of many instruments is the outcome of lengthy evolutionary processes, the kinematical principles first applied to the theory of instruments by Clerk Maxwell may with advantage be applied to the discussion of any problem, and especially new problems, in mechanical design. Prof. Pollard, of the Technical Optics Department, has already lectured to the Royal Society of Arts on this subject ; by his kindness I am exhibiting an interchangeable nose piece and squaring-on eyepiece, for the microscope, which are designed on strict kinematic principles. They allow for the squaring on and centring of the objective, which can be removed and replaced exactly in the same relative position, being constrained at six points only and held in position by gravity whether the microscope tube is vertical or horizontal. It is fully described in the proceedings of the Optical Convention.

In a recent book on Optical Measuring Instruments, I emphasised the importance of applying some of these simple mechanical considerations to the design of measuring microscopes and the like, and pointed out the deficiencies of some of the present designs. It is interesting to note that these points are met in an ingenious manner in a new micrometer microscope recently produced by Messrs. Adam Hilger, Ltd. It is to be hoped that Prof. Pollard's advocacy of the geometric principles of designs will meet with the success it deserves.

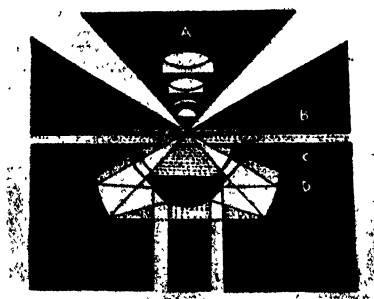


FIG. 32. The Beck dark-ground illuminator.
 A. Objective. B. Slide. C. Front component (stationary).
 D. Back component (movable).

MICROSCOPY.

The last general subject we shall consider is the subject of microscopy and recent advances in connexion therewith. In order to understand the modern developments we may go back to the days before 1850 when achromatic microscopes objectives were indeed employed, but only "dry" lenses. The greatest "numerical aperture" obtainable in practice with such lenses is 0.95. Although water immersion systems were introduced by Amici and Hartnack, and used widely from about 1860 onwards, the importance of the immersion medium in allowing the increase of numerical aperture was only pointed out by E. Abbe in 1873. Abbe showed that the resolving power of a microscope objective is dependent on the numerical aperture, and advanced a systematic explanation of the resolution of the images of objects of regular structure. The English microscopist, J. W. Stephenson, then suggested the use of an immersion liquid of higher refractive index, and Abbe produced in 1877 a lens working at NA 1.25, using a mixture of turpentine and oil of cloves for immersion fluid, whereas, the highest previous attainment had been 1.10 approximately. Subsequently to that time lenses up to NA 1.50 have been produced, although the majority of the best work is done with apochromatic lenses of numerical apertures in the neighbourhood of 1.3, using cedar oil as the immersion fluid.

An elementary discussion shows that the distance, d , of two elements of a structure just capable of resolution under certain circumstances is given by $d = 0.5 \lambda / (\text{N.A.})$ where λ is the wave length of light and N.A. is the "numerical aperture." Any microscopist will realise the tremendous world of knowledge which has been opened out by the increase of possible NA from about 0.85 to 1.3 or over, which has been accomplished by the development of immersion systems. Abbe's first 1.25 lens† showed a striking improvement in its rendering of *Pleurosigma angulatum*. Carpenter* describes how a saprophytic organism previously known to possess a nucleus from observations with lenses of lower NA, was shown to exhibit the nucleus full of fine structure by the employment of a homogenous immersion lens. The modern knowledge of bacteriology would have been absolutely impossible without the immersion lenses.

It is possible, especially if using homogenous light, to push the numerical aperture of immersion systems up to 1.6 or higher, using dense glass and immersion fluids of suitably high refractive index; and, moreover, the objectives of this type can be made very free from higher spherical aberrations, so that there is perhaps still room for work along these lines, but a step up from 1.3 to 1.6 does not represent a *very* great advance.

Kohler† suggested in 1904 that ultra-violet radiation might be employed for obtaining images of greater resolution, and Messrs. Zeiss produced a lens of actual numerical aperture 1.25 for use with homogenous radiation of wave-

† *Trans. Opt. Soc.*, 19 (1917), 49.

* *The Microscope, etc.*, Carpenter and Dallinger, 1901.

† *Zeit f. Mikrosk.* 21 (1904), 129.

length 0.275μ , which can be easily obtained with a quartz monochromator from the condensed cadmium spark. This lens was constructed from fused quartz, and can be employed with projection eyepieces in which the lenses can be made of crystalline quartz, owing to the comparatively modest angular breadth of the refracted rays in the eyepiece.

The condenser, slide, and all illuminating parts have naturally to be constructed in quartz. Rough focussing can be accomplished by the use of a fluorescent eyepiece.

The greatest difficulty in using the system is just that of finding the exact focus. The depth of focus in the image space is extraordinarily small, something like one hundred-thousandth of an inch, so that obtaining a sharp image is a matter of extreme difficulty, and could only be done at first by a series of perhaps a hundred or more trials.

This technical difficulty, and the coming of the War, were sufficient effectually to stop full developments for a good many years. However, the question has now been taken up once more.

The formula quoted above, $d = 0.5\lambda/(\text{NA})$, stands like a gigantic barrier in the way of the "seeing" of finer and finer structures. We have fortunately other modes of exploration, but it is certainly highly desirable to push along the road of seeing by all available means, and shortening the wave-length offers the only practicable route for any considerable advance. In the investigations of bacteriology, organisms of a wide range of fineness are known. With the aid of modern microscopes we can separate two points in an object separated by about $\lambda/3 = 0.18\mu$ (where μ is one-thousandth of a millimetre) using green light. By using ultra-violet radiation we might distinguish two points separated by 0.09μ . Some of the estimated sizes of molecules are:—Starch $.005 \mu$ (Lobry de Bruyn), ethyl alcohol $.0005 \mu$ (Jaeger), hydrogen $.0001 \mu$ (Meyer). Thus we should certainly require to be able to utilise a far greater range of wave-length before we could resolve the parts even of the coarsest of the molecules mentioned above. But certainly there cannot be room for a very great number of coarse "organic" molecules along the diameter of the smallest visible living cell, and considerations based on the phenomena of surface tension and molecular movements probably set a limit to the size of the living cell. The viruses of certain diseases are capable of passing through a porcelain filter, and although one such virus (that associated with the Rous fowl sarcoma) is known to contain a culturable micro-organism, there are several which have not been identified as such. The prospect is most tempting; shorten the usable wave-length a little and discoveries of the greatest importance may be waiting.

Hence in recent times renewed efforts have been made by Barnard using improved apparatus and methods of working, and already it seems that some structures and features of micro-organisms which are un-resolvable with visible light can be shown by ultra-violet radiation.

The work has been immensely facilitated by the employment of a new type of dark-ground illuminator due to Messrs. R. and J. Beck. This is shown in Fig. 32, and will be seen to be of a focussing type so that it can be adapted for use with various thicknesses of slide. It also allows a much greater aperture (1.2 N.A.) to be used in the observing objective.

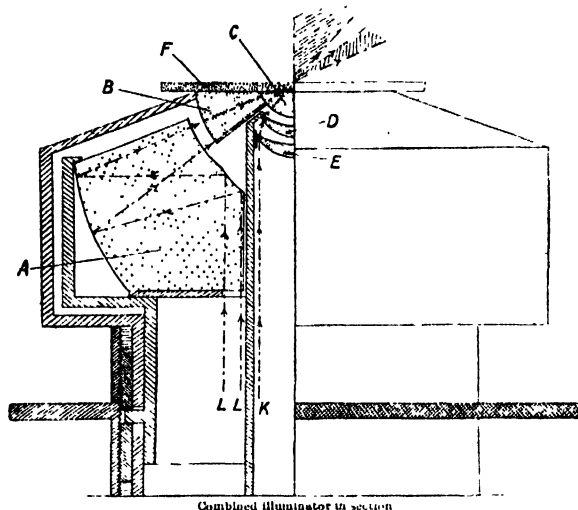


FIG. 33. Concentric type condenser and illuminator.

- A. Movable component of dark ground illuminator (glass).
- B. Front " " " " " (quartz).
- C. { Condenser components in quartz.
- D. {
- E. {
- F. Slide (quartz).

This dark-ground illuminator, used with visible light, can be built up concentrically together with a quartz condenser for use with ultra-violet radiation. In making a photograph by Barnard's method, the image is first found visually with the aid of the dark-ground illuminator using an objective of the ordinary type. The objective is then changed for one designed for homogenous ultra-violet radiation, and the illumination is changed from the green-line of mercury to that of a strong line in the ultra-violet region of the cadmium spark spectrum. The arrangement of condensers is shown in Fig. 33.

In mentioning "dark-ground" apparatus, it is interesting to find that Messrs. Carl Zeiss introduced a new model of the Siedentopf cardioid condenser for dark-ground illumination in 1925; the lower limit of the numerical aperture of the condenser is about 1.2, and the admissible aperture of the objective used with it is 1.05. The use of a specially-designed apochromatic objective of this aperture produces results superior to those obtained by the use of special stops; another lens of the achromatic type is fitted with an iris diaphragm.

The modern tendency is to attach great importance to dark-ground methods.

Fig. 34 shows a new apparatus, built by Messrs. R. and J. Beck, Ltd., to Mr. Barnard's design, for microscopy with ultra-violet radiation. It embodies an interferometer device consisting of a pair of Fabry-Perot mirrors, one attached to the stage and the other to the body, so that the movement of the latter with respect to the former, can be estimated from the movement of the interference fringes. This method, due to Barnard, is of great utility in checking the accuracy of the mechanical parts, and, like the dark-ground illuminator, is also used on ordinary microscopes.

Great accuracy of centring in condenser and objective, and perfect symmetry of illumination are necessary to obtain the best results in high power microscopy. The accuracy and delicacy, too, of the fine adjustment must be much greater for ultra-violet work than in ordinary microscopes, especially when the method of focussing mentioned above is employed. In the apparatus by Messrs. R. and J. Beck a specially fine movement, free from back-lash, has been provided.

By visual observation and photography with ultra-violet radiation Barnard has described a type of organism associated with sarcoma and carcinoma, in which the cell propagation is of a characteristic type resembling that which occurs on a larger scale in the organism of bovine pleuro-pneumonia, which is observed as a small particulate body about $0.2\ \mu$ in diameter. This appears to depend for its reproduction on the presence of a larger spheroidal body, developable from the particulate form, and thus forming the host on which further particulate forms can grow.

While Mr. Barnard's work represents a triumph in the face of the greatest difficulties it is by no means certain that the available equipment is adequate to yield the optimum results from the use of ultra-violet radiation. We may remind ourselves that in thirteen years between 1877 and 1890 the organisms of tubercle, glanders, diphtheria, typhoid fever, cholera, and tetanus were discovered. It is no accident that this progress came just after the introduction of homogenous immersion lenses. Yet what undisputed major discoveries have been made in any field of microscopy by the ultra-violet systems which have been available for the 22 years since about 1905? We must remember, too, that the early work was associated with the result of the extension of aperture, say, from 0.9 to 1.25 (it is doubtful how far the larger aperture lenses up to 1.6 were really effective), while the ultra-violet method should extend the aperture from 1.25 to the equivalent of 2.5. Why, then, has this extension been so comparatively unfruitful. Space forbids the discussion of the possible contributory causes, but it may be mentioned that it is by no means certain that fused quartz of the quality necessary for the optimum performance of the objectives has ever yet been produced.

The necessity for intensive work on the apparatus and methods is evident, and such is already in progress, as will be evident from the above remarks on recent work and apparatus. It is not too much to hope that a new extension

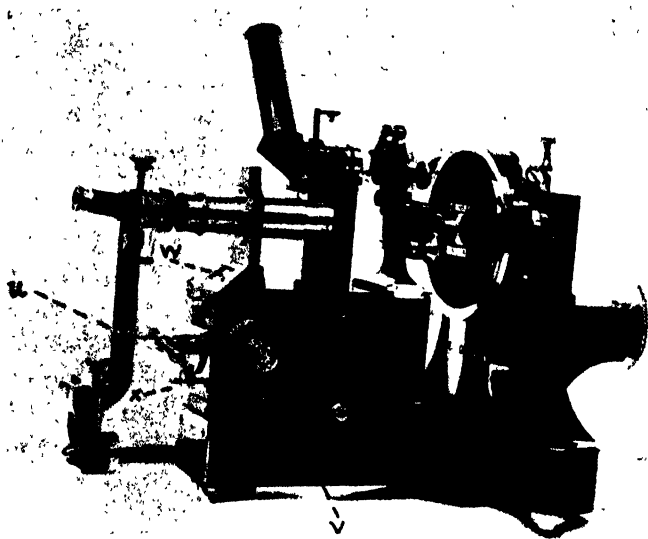


FIG. 34. The ultra-violet microscope.
 U. Coarse adjustment. V. Fine adjustment.
 W. Window for viewing micrometer dial.

of microscopy is at hand, and one from which much is to be expected. We are taking up the subject now in the Technical Optics Department of the Imperial College, and hope soon to be in a position to give instruction in the methods of ultra-violet microscopy.

Turning to another branch of microscopy, the methods of the so-called ultra-microscopy have been considerably developed. Siedentopf and Zsigmondy's* original orthogonal illumination, in which the intense beam was produced from a microscope objective, was improved in 1913 by Zsigmondy†, who used an immersion lens for the illuminator. The various dark-ground condensers are also used for the study of ultra-microscopic objects. The state of polarization of the diffracted light, the phenomena of pleochrism, and the colouration of the images are all indicative of the structure, directions, and singularities of the particles, even when these are not directly shown by the diffraction image.

Then, too, the optical methods of petrographic research hitherto mainly concerned with geological work have found new applications in biological work and the study of colloids. The title of Prof. Bragg's recent lectures, "The Imperfect Crystallization of Common Things," gives the key to the question. Such structures as nerve fibres, threads of gum, cell walls, silk

* *Colloids and the Ultra-microscope*; by Zsigmondy, trans. by J. Alexander, New York, 1905.

† *Phys. Zeit.*, 14 (1913). 975.

fibres, and many other things are found to possess highly characteristic molecular arrangements, and are, in consequence, strongly doubly refracting ; so much so that the " fast " and " slow " vibration directions are easily recognised, using an ordinary polarization microscope, even with the small thickness which the majority of such specimens have.

In some spherical globules there are symmetrical circular molecular arrangements, and it almost raises the question as to whether it may not be possible, when we understand these things better, to make something which will act on X-Rays, or radiations of very short wave-length, so as to produce images just as a zone plate will produce diffracted images with visible light. Already we have the use of crystals with their space-lattice structure which acts like a linear diffraction grating with X-Rays, and so perhaps the extension of seeing (by the aid of photography), even down to molecules and atoms, is not quite entirely hopeless.

CONCLUSION.

These lectures must now be concluded. " Optics " is a wide subject ; we have done no more than look at some of its problems and some few examples of the ways in which they are being solved for the benefit of science and industry. Many broad fields of progress, such as in photometry—the measurement and recording of light, we have passed unnoticed. We have found no space to discuss the fascinating speculations as to the nature of light itself. Many of the most recent and ingenious alliances of optical and electrical methods, such as used by Prof. Rankine for the reproduction of speech, and by Dr. Fournier d'Albe for the counting of interference fringes must perforce be passed in silence. I said at the commencement of these lectures that the optical instrument maker has a wide field of activity, and I think you will agree that this is no idle claim.

The lectures have dealt with some of the activities of the Technical Optics Department, which has been in existence for nearly ten years ; its past students are now " making good " in many branches of the optical world. I have tried to illustrate some of our research activities ; the importance of fundamental research on the root problems is not always realised as well as it should be. The production of commercial inventions is important enough for the manufacturer, and rightly so, but this cannot proceed healthily unless stimulated by the fundamental work in which knowledge, and the power which comes from knowledge, is sought for its own sake.

My sincere thanks are due to a number of firms who have been kind enough to lend lantern slides or apparatus for exhibition at the lectures ; these are Messrs. Barr and Stroud, Ltd. ; Messrs. R. J. Beck, Ltd. ; Messrs. C. F. Casella and Co., Ltd. ; Messrs. Chance Bros. and Co., Ltd. ; Messrs. J. H. Dallmeyer, Ltd. ; Sir Howard Grubb, Parsons and Co. ; Messrs. Adam Hilger, Ltd. ; Messrs. Taylor, Taylor and Hobson, Ltd. ; The United Kingdom

Optical Co., Ltd.; Messrs. E. R. Watts and Son, Ltd.; Messrs. Carl Zeiss (London), Ltd. I am also greatly indebted to Sir Herbert Jackson, F.R.S., and the staff of the British Scientific Instrument Research Association, Ltd., for valuable information regarding abrasives, and other help. Acknowledgments are also due to some of the above firms for permission to reproduce illustrations, and to the Sport and General Press Agency, Ltd., for permission to use Fig. 9.

NOTES ON BOOKS.

DEVELOPMENT AND PRESENT POSITION OF CHEMICAL ANALYSIS BY EMISSION SPECTRA. By F. Twyman. 2s. 6d. net.

THE POLARIMETER, A Lecture on the Theory and Practice of Polarimetry. By Vivian T. Saunders. London: Adam Hilger, Ltd. (24, Rochester Place, N.W.1). 1s. 6d. net.

So paramount is the position of Messrs. Hilger in relation to the utmost refinements in Spectrometer and Polarimeter construction that these two booklets issued by them have quite special interest and importance.

Mr. Twyman, who for some years has been the technical head in the Hilger workshops, gives us the substance of two lectures on the results obtainable with the best modern apparatus, the essential features of which he describes and illustrates. He foreshadows the time when many complex approximately quantitative analyses may be carried out almost instantaneously with minute traces of the material (pp. 6, 21, 31 and 37). Every laboratory worker and physicist should study the whole of Mr. Twyman's booklet with the utmost care, as he links together various strains of progress, gives references, calls for a pause, and looks to the future.

The booklet of Mr. Saunders is of a different character, but equally entrancing to the advanced student, as the present status of Soleil's saccharimeter is compared with the original form which may be considered to have come into being in 1845 (p. 16). The term polarimeter is now generally used as the instrument is not only used for sugar, but also in relation to the manufacture of starch, oils, rubber, glassware and even to stress to be expected in portions or members of mechanical structures.

In one sense, the most delightful part of the booklet given to us by Mr. Saunders is the preliminary part, in which he traces the idea of polarisation of light from the observation of Bartholinus on the double refraction of Iceland spar (p. 7), gives us scheme-drawings to assist in grasping the theory of polarisation, as also the rotation of the polarised ray (pp. 9-10), and then leads his readers to an understanding of the principles involved in the action and use of the polarimeter.

HIGH VACUA. By G. W. C. Kaye. With illustrations. London: Longmans, Green and Co., Ltd. 10s. 6d. net.

Those who were present at Dr. Kaye's delivery of a course of three Cantor Lectures on High Vacua, early in 1926, should take special pleasure in owning and reading a copy of this profusely illustrated volume, which we may hope to see in many future editions and taking a place among the classics of technological literature.

The author's considerable extensions in treatment since the delivery of the lectures in the theatre of the Society, are well exemplified by comparing the half-page which follows the heading, "Industrial Applications of the Steel Pump" on p. 1026 of the *Journal*, October 1, 1926, with the fully illustrated and detailed account of the most recent industrial applications as given in the book under notice. This account extends over four pages (110-113), and is supplemented by details of experiments to ascertain how far cadmium may replace mercury as the boiling metal in a vapour condensation pump, the author telling us that "cadmium possesses the advantage of a negligible vapour pressure at atmospheric temperature, and so a vapour trap becomes unnecessary (p. 113).

As regards the profusion in illustration, we may particularise by pointing out that the eighteen illustrations as given in the Society's reports of the lectures, are almost tenfolded in the book; the exact number being 175. The more important of these are printed in plate form, the frontispiece being *Iconismus XI* from the *Experimenta Magdeburgica* of Otto von Guericke (1672), and, apart from this and the descriptive text incident to it, we have a remarkably full and lucid account of early work. Dr. Kaye tells us that the "art of pumping in the seventeenth century was not confined to piston pumps." In his Fig. 2, p. 8, he shows us the construction of the gear pump of Schwenter (1636) in which there is a chamber-train somewhat like that of Root's blower, but with four teeth on each rotor, while Fig. 3 shows us a present day form for approximate evacuation in which the number of teeth is increased and the chamber is more exactly fitted to the rotors. On p. 9, Fig. 4 shows us the internal parts of Prince Rupert's water-bolt, (about 1650), which is a chamber pump in which a non-centric rotor carries a scraping vane, while Fig. 5 shows how Gaede (in 1907) applied a similar principle to the construction of a high-vacuum pump, and by turning to p. 76 and reading onwards we are taught to regard the Gaede pump as a first step in a series of mechanical devices for producing high vacua.

CIVIL ENGINEERING SPECIFICATIONS AND QUANTITIES. By G. S. Coleman and G. M. Flood. London: Longmans, Green & Co., Ltd. 10s. 6d. net.

This carefully indexed volume of xvi + 282 pages, gives a remarkably full and lucid study of the many complications, difficulties and misunderstandings which may arise in relation to civil engineering contracts, in which the unknown or unexpected creates an atmosphere of uncertainty far beyond that involved in ordinary mercantile or manufacturing contracts.

Vitruvius, who seems to have served as an engineer under Julius Cæsar, and who takes us back about two thousand years, is perhaps the most ancient writer on this subject, whose works are now easily available. After Vitruvius had retired from his strenuous military duties, he wrote a comprehensive treatise, *De Architectura*, in ten books, and he not only includes building and civil engineering with much interestingly detailed chemistry and mechanics, but also social and business elements with quotations from previous writers.

The tenth book of Vitruvius commences with a mention of an old law of the Ephesians, by which an architect whose estimate for a public work proves sufficient, is to be considered worthy of being decorated with honours and official distinctions. (" . . . decretis et honoribus ornatur). When excess in expenditure was not more than one-fourth of the estimate, the people bore the extra expenditure, but no punishment was ordered for the architect. If, however, there was expenditure beyond this additional fourth, the architect was held liable for it. Vitruvius regards the somewhat rigid system of the old Grecian city as just, and regrets

greater slackness in Rome. Subsequently he reverts to Ephesus, and mentions a contractor, Pæonius, who, having undertaken to bring a block of stone from the quarry to the temple, devised an ingenious modified system which Vitruvius describes concisely and lucidly with measurements, but the new feature led to such delay as to exhaust the resources of Pæonius before the stone was brought to its destination.

Legal considerations figure largely in the volume now under notice; an undercurrent of legal instruction running aptly and pertinently with the technical and other aspects. Thus, in the preface, we are reminded of a main source of misunderstanding, a lack of certainty as to "how literally the clauses will be interpreted, and how far the strict letter of the text will be enforced." And, turning to page 72, we read that sand for concrete and mortar is specified to be "clean," and farther on in the same sentence we are told that the sand must be "free from loam, clay, or any organic matter." Strictly speaking, cleanness is to be regarded as a relative rather than an absolute condition, and the degree of cleanness required by a chemist for the inside of his combustion tube in the case of an organic analysis may be considerably less than that required for the glass mirror of a telescope before silvering; while some of the methods adopted "to outgas the plate and grid" of a modern ionic valve carry the idea of cleanness several stages further. These refinements, although interesting from many standpoints, and of primary importance to the student of pure science, have no place or function in the book under notice; the language of plain common (or general) sense, as accepted in everyday life, and acted on in our law courts being the basis of thought and phrasing with the authors. Thus as regards the sand, we are reminded that a "lime or cement test is generally stated," also that "a common practice is to take a small sample and rub it between the fingers. If there is any stain, clay or organic matter is most probably present." A ready comparative colour test for organic matter, by use of a weak solution of caustic soda, is mentioned, and the desirability of providing mutually approved samples of the various materials "before the work starts," is emphasised. We turn, however, from the comprehensive chapters on materials, workmanship, taking off, abstracting, certifying for payment, and arbitration, and we revert to the preface. Here we are taught that a mutual belief in fair intentions is, perhaps, the best of all securities.

This work, like so many of our better-grade text-books, has been carefully constructed from materials gathered together during the routine of teaching, and as it now stands it is likely to do great service by showing how to avoid expensive misunderstandings.

FACTORY LEGISLATION AND ITS ADMINISTRATION. By H. A. Mess. London: P. S. King & Son, Ltd. 12s. 6d. net.

This book gives a concise but full account of factory legislation in Great Britain since 1891, with due consideration of, and references to, previous legislation and history. The volume is made easy for reference by a full tabulation of contents (pp. v-vii) and a good index; while the chronological table (pp. 217-218) and the Select Bibliography give it a special value to the student.

It must not be supposed from the above that the work under notice is merely a bare record and tabulation, as in many places interesting digressions and speculations are embodied. For example, on p. 196 the inter-relation of Factory Acts and Education Acts is considered, our Education Act of 1870 being practically a prohibition of child labour in the factory. In considering lead poisoning the author points out that one must not draw conclusions too hastily, and the reasons are given. In chapter XI, pp. 136-148, the international aspects of the factory question are touched upon, with very full notes and references.

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*All communications for the Society should be addressed to the Secretary, John Street,
Adelphi, W.C.(2.)*

NOTICE.

FUND FOR THE PRESERVATION OF ANCIENT COTTAGES.

ADVISORY COMMITTEE.

An Advisory Committee in connection with the Fund for the Preservation of Ancient Cottages has been constituted as follows :—

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<i>Ministry of Health</i>		*RAYMOND UNWIN, Esq., F.R.I.B.A.
<i>National Council of Social Service.</i>		A. C. RICHMOND, Esq.
<i>National Gallery, Trafalgar Square.</i>		C. H. COLLINS BAKER, Esq.
<i>National Trust.</i>		*NIGEL BOND, Esq., O.B.E.
<i>Royal Academy of Arts.</i>	...	SIR GILES GILBERT SCOTT, R.A., F.R.I.B.A.
<i>Royal Archaeological Institute</i>	...	WALTER H. GODFREY, Esq., F.S.A., F.R.I.B.A.
<i>Royal Automobile Club.</i>	...	ARTHUR J. DAVIS, Esq., F.R.I.B.A.
<i>Royal Historical Society.</i>	..	HAROLD SANDS, Esq., F.S.A.
<i>Royal Institute of British Architects.</i>		OSWALD P. MILNE, Esq., F.R.I.B.A.
<i>Royal Photographic Society.</i>	...	THOMAS H. B. SCOTT, Esq., F.R.P.S.
<i>Rural Industries Bureau.</i>	...	W. W. BLAIR-FISH, Esq.
<i>Scapa Society.</i>		SIR ALBERT GRAY, K.C., K.C.B.
<i>Society for the Protection of Ancient Buildings</i>		*A. R. POWYS, Esq.
<i>Surveyors' Institution.</i>	...	PERCY F. TUCKETT, Esq., F.S.I.
<i>Town Planning Institute.</i>	...	E. G. ALLEN, Esq., F.R.I.B.A.
<i>Victoria and Albert Museum.</i>	...	R. P. BEDFORD, Esq.

*Member of the Executive Committee. The Executive Committee was appointed at the first meeting of the Advisory Committee on June 15th, 1927.

REPORT ON THE COMPETITION OF INDUSTRIAL DESIGNS, 1927.

INTRODUCTION.

The Annual Competition of Industrial Designs was held for the fourth time this year. In certain sections it is gratifying to note that the judges report a very marked advance as compared with the work submitted at previous competitions. The prize-winning designs for wrought iron gates were excellent both in conception and execution. The designs for tapestry and moquette piece goods, for cretonnes, for printed and woven dress goods and printed furnishings included much admirable work, whilst in the Book Production Section, which has hitherto been poor, there were many excellent specimens of printing. In the Pottery and Glass Section the number of entries jumped up to 318, as compared with 94 last year, and the quality of the pottery designs has increased as remarkably as the quantity. A great many of these candidates come from the junior departments of art schools in the pottery districts, and it is satisfactory to find that so much young talent is being trained in these quarters. The general average of the posters is also considerably higher than that of the preceding competitions. On the other hand it must be admitted that in one or two sections the work is disappointing. In the designs for furniture there was a general lack of originality and of proper appreciation of the principles of furniture construction, while the designs for decorative architecture were poor, as were most of those for silk fabrics and carpets.

This year, for the first time, a prize was offered for topographical drawings, and this drew some excellent entries.

A large number of the prizes offered this year were provided by firms for designs for special objects. These and the general prize funds have been provided by the generosity of those whose names are printed as an Appendix to this Report. All the money subscribed to the Prize and Scholarship Fund has been devoted to prizes and scholarships, without any deduction being made for the expenses of the competition.

Firms and individuals are invited to offer prizes for the Competition of 1928. The prize-winning designs become the property of the firms. It will be noticed at the Exhibition that in one or two cases these designs have been removed, as the owners are anxious to get them on to the market as soon as possible. No doubt the exhibition loses a little by the absence of this work, but on the other hand the anxiety on the part of the owners to secure the designs at once is proof of the practical value of the competition both to manufacturers in search of designs and to designers in search of employment.

It has been the practice at the conclusion of the exhibition in London to send sections of the work to centres likely to be specially interested in them. Thus the Pottery designs have been exhibited in the Potteries; in 1925 the textiles

designs were shown at Manchester, and last year at Leeds. Considerable interest was roused in these centres in this way, and as a direct result of the Leeds exhibition three or four young designers secured good permanent appointments with well-known firms.

For the benefit of those whose work is approved by the judges for exhibition, a Bureau of Information has been opened where their names can be enrolled if they desire to obtain employment as designers. The information is placed at the disposal of manufacturers, and it is hoped that the Bureau will be of service both to manufacturers and designers.

The Council desire to express their appreciation of the generosity of the Goldsmiths' Company, who undertook to provide all the prizes in the Pottery and Glass Section this year; and they further desire to convey their thanks to those firms and individuals who have provided the prizes in the other sections, to the Judges who devoted much time and care to a very difficult task, and to Lieut-General Sir William T. Furse, K.C.B., D.S.O., Director of the Imperial Institute, through whose kindness the Society received permission to judge the designs and to hold an exhibition of selected specimens in the Indian Pavilion.

NUMBERS OF ENTRIES.

The total number of competitors who entered for the various sections of the Competition was 745. Of these, 571 were students of Schools of Art, and 174 non-students.

The number of designs submitted was 2,224, divided as follows :—

Architectural Decoration	..	..	..	..	..	..	224
Textiles	..	..	..	..	..	..	487
Furniture	..	..	..	..	..	..	101
Book Production	..	..	..	..	..	..	220
Pottery and Glass	..	..	..	..	..	..	318
Miscellaneous—							
Messrs. Cadbury Brothers, Ltd.	..	..	..	..	..	..	51
Messrs. Bryant & May, Ltd.	..	..	..	..	..	..	202
Messrs. J. S. Fry & Sons, Ltd.	..	..	..	..	..	..	236
Messrs. Fryer & Co. (Nelson), Ltd.	..	..	..	..	..	..	91
Messrs. Healey's Tyre & Rubber Co., Ltd.	..	..	..	..	..	..	123
Messrs. Rowntree & Co., Ltd.	..	..	..	..	..	..	11
Underground Group of Companies	..	..	..	..	..	..	132
Messrs. Hugon & Co., Ltd.	..	..	..	..	..	..	28
Total	..	..	..	..	..	..	2224

The Schools of Art from which competitors entered were :—

[The numbers in brackets show the number of competitors from each School].

Architectural Association School (1); Miss E. Y. Andrews' Studio, 7, Beresford Road, Birkenhead (1); Barnstaple School of Science and Art (4); Barnsley School of Arts and Crafts (1); Barrow-in-Furness School of Arts and Crafts (2); Bath Municipal Technical College (4); Batley School of Art and Crafts (1); Battersea Polytechnic School of Art and Crafts (20); Birmingham Central School of Art (2); Blackburn Art School (5); Blackheath, Lee, Lewisham and Greenwich School of Art and Crafts (2); Bournemouth Municipal College Art School (7); Bradford College of Art and Crafts (7); Bristol Municipal School of Art (5); Bristol Royal West of England Academy School of Architecture (1); Bromley and Beckenham Schools of Art (6); Bromsgrove School of Art (1); Burslem School of Art (23); Bury School of Art (1); Brighton Municipal School of Art (5); British and Dominions School of Drawing, Ltd. (11); Brixton L.C.C. School of Building (3); Black and White Studios (2); Camberwell L.C.C. School of Arts and Crafts (3); Cambridge School of Arts and Crafts (2); Carlisle Art School (4); Chesterfield School of Art (1); Clapham L.C.C. School of Art (2); Croydon School of Art (15); L.C.C. Central School of Arts and Crafts (10); Chelsea Polytechnic (6); Cardiff School of Art and Technical College (2); Cheltenham School of Art (1); Darlington School of Art (2); Derby School of Arts and Crafts (1); Dunfermline Lauder Technical School (4); Edinburgh College of Art (7); Farnham School of Art (5); Gosport Secondary School (1); Gravesend School of Art (1); Glasgow School of Art (3); Goldsmiths' School of Art (2); L.C.C. Hackney Institute (1); Halifax Municipal Technical College (11); Hammersmith L.C.C. School of Arts and Crafts (11); Hanley School of Art (8); Hastings School of Art (6); Heatherley School of Fine Art (4); High Wycombe, Wycombe Technical Institute (7); Mr. John Hassall's Studio, 3, Stratford Studios, Stratford Road, Kensington (2); Hornsey School of Art (14); Hyde School of Art (3); Hove, Wick Studio (5); Mr. John Hurst's Studio, "Fairfield," Harwood Lane, Gt. Harwood (1); International Correspondence Schools, Ltd. (20); Ipswich School of Arts and Crafts (2); Sir John Cass Institute (1); Keighley School of Art and Crafts (4); Kidderminster School of Art (5); Leeds College of Art (26); Leicester College of Arts and Crafts (14); Liverpool City Art School (38); Longton School of Art (3); London School of Printing and Kindred Trades, Stamford Street, S.E. (9); Macclesfield School of Art (5); Maidenhead School of Art (4); Manchester Municipal School of Art (25); Manchester College of Technology (1); Morley Technical School (1); Newbury Technical Institute (1); Nottingham School of Art (16); Nottingham Correspondence College for Applied Designs, Ltd. (2); Newport, Mon., School of Art and Technical Institute (2); Newcastle-under-Lyme School of Art (1); Northampton School of Arts and Crafts (1); Oxford School of Art (5); Oldham Municipal School of Art (1); Preston Art School (2); Putney L.C.C. School of Art (9); Paisley Technical College and School of Art (2); Reay Central School (5); Richmond School of Art (3); Royal Academy School of Architecture (1); Reading University Art Dept. (1); Royal School of Needlework (1); Rochdale School of Art (2); Mr. J. H. Roberts' Studio, 30, Royal Crescent, W.11. (1); Royal College of Art (8); Regent Street Polytechnic School of Art and Architecture (3); Sheffield College of Arts and Crafts (34); Southend-on-Sea Municipal School of Arts and Crafts (3); Stourbridge School of Art (2); Swindon Art School (1); Salford School of Art, Royal Technical College (4); St. Martin's School of Art (3); South London Art School (1); Slade School of Art (1); Taunton County and Borough School of Art (2); Thanet, Margate and Ramsgate Schools of Art (3); Tonbridge School (1);

West Bromwich, Ryland Memorial School of Art (7); Wolverhampton Municipal School of Art and Crafts (3); Wordsley School of Art (5); Weymouth School of Art (1); Westminster School of Art (13); Woolwich Polytechnic School of Art (1); Windsor Art School, Royal Albert Institute (2); Yarmouth, School of Art (1).

NAMES OF JUDGES.

The Judges were appointed by the Council on the recommendation of the various Sectional Committees. Their names are as follows :—

ARCHITECTURAL DECORATION.

SUB-SECTION 1. *Decorative Architecture. Designs for Entrance Hall to a block of high-class flats. Prize offered by the Royal Society of Arts.*

Mr. Murray Adams-Acton; Mr. Godfrey Giles; Mr. Stanley Hamp, F.R.I.B.A., and Professor A. E. Richardson, F.R.I.B.A.

SUB-SECTION 2. *Topographical Drawing. Prize offered by the Royal Society of Arts.*
Professor A. E. Richardson, F.R.I.B.A.

SUB-SECTION 3. *Designs for Wrought Iron Gates. Prizes offered by Messrs. Baguès, Ltd., and Mr. A. W. Martyn.*

Mr. Arthur J. Davis, F.R.I.B.A. (Chairman of the Section), M. Paul Guieu, and Mr. Fabian Trollope.

SUB-SECTION 4. *Design for a Pedestal of an Equestrian Statue. Prize offered by the Chairman of the Section.*

Mr. Arthur J. Davis, F.R.I.B.A., and Mr. Stanley Hamp, F.R.I.B.A.

SUB-SECTION 5. *Design for an electric light fitting. Prize offered by Messrs. Hailwood and Ackroyd, Ltd.*

Mr. Murray Adams-Acton, Mr. Fabian Trollope, and Mr. E. A. Hailwood.

SUB-SECTION 6. *Design for a Fireplace, with a Mantelpiece of marble, for an aeronautical club. Prize offered by Messrs. Shuffrey and Co.*

Mr. Arthur J. Davis, F.R.I.B.A.

SUB-SECTION 7. *Lewis Berger Scholarship.*

Mr. Murray Adams-Acton.

TEXTILES.

SUB-SECTION 1. *Designs for Silk Fabrics for furniture and decoration. Prizes offered by Messrs. Warner and Sons.*

Mr. R. H. Garton, Mr. A. F. Kendrick, and Mr. Cloudesley Warner.

SUB-SECTION 2. *Sets of three repeating Designs for Tapestry and for Moquette, etc., piece goods. Prizes offered by Messrs. Arthur H. Lee and Sons, Ltd.*

Mr. Thorold Lee and Mr. James Morton.

SUB-SECTION 3. *Designs suitable for printing on Cretonne. Prizes offered by Messrs. Simpson and Godlee, Ltd.*

Mr. R. H. Garton, Mr. L. V. Gladwell, and Mr. A. J. B. Wace.

SUB-SECTION 4. *Design for a seamless Axminster Square, suitable for a drawing room or boudoir. Prize offered by the Carpet Manufacturing Co., Ltd.*

Mr. E. H. O. Carpenter, Mr. A. B. Cowtan, O.B.E., and Mr. A. F. Kendrick.

SUB-SECTION 5. *Designs for Linen Table Damasks. Prize offered by Messrs. Hay and Robertson, Ltd.*

Mr. R. H. Garton and Mr. C. E. Mann.

SUB-SECTION 6. *Sets for Designs for (1) Printed Dress Goods, (2) Printed Furnishings (3) Woven Dress Goods. Travelling Studentships offered by The Tootal Broadhurst Lee Company, Ltd.*

Mr. T. C. Dugdale and Mr. Arthur Lines.

Sir Frank Warner, K.B.E. (Chairman of the Section) was also appointed a general referee in all sub-sections.

FURNITURE.

Mr. Octavius Satchell (Chairman of the Section), Mr. H. Allport, Mr. S. D. Bianco, Mr. H. D. Searles-Wood, F.R.I.B.A., Mr. H. P. Shapland, A.R.I.B.A., and Mr. W. Stewart-Greene, together with Mr. Mount, representing Messrs. Waring and Gillow, and Mr. Gribble, representing Messrs. Frederick Tibbenham, Ltd.

BOOK PRODUCTION.

Mr. J. A. Milne, C.B.E. (Chairman of the Section), Major R. Leighton, Mr. C. J. L'Estrange and Mr. J. Stuart.

POTTERY AND GLASS.

Mr. E. R. Edis (Chairman of the Section), Mr. Joseph Burton, Mr. F. Stuart, and Mr. W. Savill.

MISCELLANEOUS.

Mr. J. A. Milne, C.B.E. (Chairman of the Book Production Committee), and Sir Bertram Mackennal, K.C.V.O., R.A., in all sub-sections, together with Mr. J. N. Hart, representing Messrs. Bryant & May, Ltd.; Mr. M. F. Gilshenan, representing Messrs. J. S. Fry and Sons, Ltd.; Mr. A. G. Chate, representing Messrs. Henley's Tyre and Rubber Co., Ltd.; Mr. A. E. Wilson and Mr. W. F. Kirby, representing Messrs. Rowntree and Co., Ltd.; Mr. H. T. Carr, representing the Underground Group of Companies, and Mr. P. Chapman, representing Messrs. Hugon and Co., Ltd.

REPORTS OF JUDGES.

SECTION I.—ARCHITECTURAL DÉCORATION.

SUB-SECTION 1. *Decorative Architecture. Design for an Entrance Hall to a block of high-class Flats.* The Judges felt that none of the designs came up to the standard expected and in view of the value of the prize offered (£50), they were disappointed at the result. There seems to be hesitation between weak and bad copying of historical work and half-hearted attempts at following the prevailing fashion. It is necessary to emphasize that what is required is sound work related to the conditions of to-day.

They were unable to recommend the award of any prize.

SUB-SECTION 2. *Topographical Drawing.* Some excellent work was submitted in this sub-section and it was considered advisable to divide the prize of £20 into one of £10 and two of £5 each.

A prize of £10 is awarded to Eric Cumine, Architectural Association School (Nos. 863 to 866), who submits a good set of measured drawings which fall within the meaning of the syllabus, the object of the competition being to secure accurate records of buildings. This competitor has an intuitive appreciation of refined architecture and should develop his powers of draughtsmanship.

A prize of £5 is awarded to Frank Ernest Georges, Rosendale, Wallands, Lewes (No. 318). This candidate has a tendency to overwork his pencil studies. His perspective is good and the subjects well chosen. His drawings, however, suffer from equality of line, and a certain woolliness. He is a painstaking draughtsman, but should develop a freer handling.

A prize of £5 is awarded to Herbert Stanley Froude, 1, Milo Road, E. Dulwich, S.E.22 (No. 552), for his topographical drawing of London Bridge and Adelaide House. This competitor combines realistic accuracy with a sense of decorative design, and introduces incidents such as cranes and shipping to enhance the character of the architecture. He has a fine appreciation of *locale*. He is advised to pay attention to detail and to beware of slickness.

Commended :

Denis Edmund Harrington, 53, The Oval, Kennington, S.E.11. (Nos. 947 and 949).

Most of the other competitors tend to follow popular taste and to copy photographs which is contrary to the spirit of the competition.

SUB-SECTION 3. *Prizes for a design for Wrought Iron Gates offered by Messrs. Baguès, Ltd., and Mr. A. W. Martyn.* The judges are of opinion that the work in this sub-section is generally of a high standard and that the details are well worked out, and in some cases exceedingly well presented. There is a very considerable improvement as compared with the designs submitted last year.

The principal considerations that the judges had in view were suitability, that the designs conformed to the period prescribed, and that they were correct in scale.

They have recommended the following awards :—

A First Prize of £50 to Endymion Leadbetter Mackenzie, 13, Palliser Road, Baron's Court, W.14. (Nos. 811 to 813.)

A Second Prize of £25 to Leonard Courtney Lewis, 166, Crowborough Road, Tooting Common, S.W.17. (Nos. 589 to 591.)

Highly commended :

Edward Henry Thorpe, Putney School of Art. (No. 452 to 454.)

Commended :

Harold Shaw, Hammersmith School of Art. (Nos. 2074 to 2076.)

An Owen Jones Medal to John Grisedale Sidebottom, Leeds College of Art. (Nos. 1763 to 1765.)

The judges consider this design interesting and showing considerable promise ; but the candidate is disqualified for a money prize as the conditions set forth in the syllabus were not adhered to.

SUB-SECTION 4. *Pedestal for an Equestrian Statue.* None of the competitors advanced a good solution of the problem set, but T. F. Firth, Leeds College of Art (Nos. 1759-62), to whom a prize of £5 is awarded, achieved a somewhat dramatic effect and shewed a clever perspective. He is advised to continue the study of architectural design, and to pay particular attention to planning, in which his work is far from satisfactory.

The other designs were found to be unworthy in that they failed both in draughtsmanship and in the proper setting of the monument in relation to the steps, etc.

SUB-SECTION 5. *Prize offered by Messrs. Hailwood and Ackroyd, Ltd., for a design for an Electrical Fitting.* The prize of £10 10s. is awarded to Reginald E. Edgecombe, 10, Lime Grove, Moseley Road, Birmingham, (No. 919), for a glass pendant decorated with a classical design of Etruscan character, which although not original, exhibits a certain sense for design and decoration.

Commended :

Percy Lumb (Morley Technical School). (Nos. 1094-5.)

SUB-SECTION 6. *Prize offered by Messrs. Shuffrey and Co., for a design for a Fireplace, including a Mantelpiece of Marble, in the vestibule of an Aeronautical Club.* The designs submitted were poor and the judges regretfully decided that none of them shewed sufficient commendable originality or technical knowledge of traditional styles to merit an award.

SUB-SECTION 7. *Lewis Berger Scholarship.* There was only one entry for the Lewis Berger Scholarship, that of Leonard C. Evetts, Newport Technical College and Institute (Nos. 2188-95), whose "evidences of study" were considered by the judges of sufficient merit to deserve the award of the Scholarship. The two sheets of architectural drawings submitted are the weakest part of the entry, but the pencil studies from nature of flowers and foliage and the lettering in Roman capitals are of considerable merit, while the remainder of the work shews good draughtsmanship and indications of careful study.

SECTION II.—TEXTILES.

SUB-SECTION 1. *Designs for Silk Fabrics for Furniture and Decoration in which one or more shuttles are used. Prizes offered by Messrs. Warner and Sons.*

On the whole, the work submitted in this Sub-Section does not maintain the standard of past years. The judges considered that none of the designs reach a sufficiently high standard to merit an award of either of the two prizes, but with the concurrence of Sir Frank Warner, who does not claim possession of the designs, they have awarded a prize of £10 to Arthur E. Dace, ("Maresfield," Baring Road, Grove Park, S.E.12) (Nos. 908 and 909.) No. 908 is suitable for reproduction and would probably be popular with a section of the public, while No. 909 is a graceful adaptation of late 18th century design.

Highly commended :

Miss Margaret E. Hays (The Mythe, Bognor, Sussex). (No. 356.) This design shows originality and skill, but would be more suitable for a printed material.

Miss Margaret J. Hendry (Farnham School of Art). (No. 1577.) This design is a promising piece of work.

Percy Peck (L.C.C. Central School of Arts and Crafts). (No. 816.) This is a practical and well-balanced design, suitable for an upholstery material.

Commended :

Thomas Isherwood (Blackburn School of Art). (No. 1503.) This design is excellent in spacing and would be very effective as a design for printed silk.

SUB-SECTION 2. *Sets of Three Repeating Designs for Tapestry and for Moquette, etc., Piece Goods. Prizes offered by Messrs. Arthur H. Lee and Sons. Ltd.*

Twenty-one sets of designs were submitted for the prizes offered for sets of three designs suitable for specific chairs which had been illustrated in the prospectus of the competition.

Although the general standard of work was higher than in former years, it is clear that many of the competitors had failed to grasp the varying requirements of the different styles of chairs, and to visualize their designs as fabrics. Much of the work was devoid of character, and showed little or no artistic feeling and a poor sense of colour.

The awards are as follows :—

The First Prize of £50 is awarded to Ernest Charles Leach (51, Marlowe Road, Wallasey, Cheshire). (Nos. 487 to 489.) These designs show a good feeling for decoration and are delightfully coloured; they are also well suited for the chairs. While they show no real originality of detail, they are well constructed, indicating also a versatility of conception, and they are up to a consistent level. The small design (No. 489) is especially successful.

The Second Prize of £35 is awarded to H. Clarence Whaitte (L.C.C. Central School of Arts and Crafts). (Nos. 1132 to 1134.) In this set of designs the judges feel that a consistent level of excellence has not been achieved. Although No. 1132 contains no new motifs, it is exceedingly happy and decorative, and the colouring is most attractive and well balanced. The whole idea behind No. 1134 is centuries old, but the designer has given it a constructional quality which is novel and pleasing. Over design No. 1133 the designer has lost marks; it is not well adapted to its purpose, while the introduction of a large naturalistic stag, that would have to be cut through the centre, is not pleasing.

The Third Prize of £15 is awarded to Miss Lilian J. Pocock (24, Warwick Avenue, W.9). (Nos. 730 to 732.) In this set of designs there is a certain novelty of idea which is very welcome, but the standard is not at all consistent. No. 730 would be almost impracticable for any of the three chairs, but might make a most effective design for very large curtains, and both this design and No. 731 show breadth of treatment and vigour of colour. No. 732, however, is far from successful and appears to be somewhat of an afterthought.

Commended :

Miss Florence D. B. Barson (Oxford School of Art). (No. 1278.) This design, though relatively small, has character, and would be useful and decorative in its own way.

Miss Vera W. Waddington (Heatherside, Gerrard's Cross, Bucks.). (No. 2183.) This design shows pleasing colour and a very effective treatment of the oak leaves, but—in common with the other designs submitted by the same competitor—seems more suitable for hand tapestry or needlework than for repeating power-woven fabrics.

SUB-SECTION 3. *Designs suitable for printing on Cretonne. Prizes offered by Messrs. Simpson and Godlee, Ltd.*

The general average of the designs submitted was decidedly in advance of those shown last year, but many were not drawn to the specified size, and were, therefore, disqualified. Some of the designs also were not suitable for reproduction as printed

fabrics. It is very satisfactory to see that young students can turn out work of such merit, especially in the case of the second prize-winner, who is recommended for an Owen Jones medal. The first prize goes to Mrs. Reynolds, whose three designs are characterised by firmness of line and vigour and originality in conception. The third prize-winner shows the influence of the Burne Jones school. The special prize goes to a young designer, whose work is promising and well suited for reproduction.

The awards are as follows :—

The first prize of £52 10s. to Mrs. Marjorie Reynolds, 59, The Common, Woolwich, S.E.18. (No. 167.)

The second prize of £31 10s. to Miss Catherine E. Stoddart (Manchester Municipal School of Art). (No. 1698.)

The third prize of £21 to Miss Winifred Orde-Ward (L.C.C. Central School of Arts and Crafts). (No. 470.)

A Royal Society of Arts Prize of £10 to Stephen Hodgkinson, 15, Clarence Road, Teddington, Middlesex. (Nos. 579 to 581.)

An Owen Jones Medal to Miss Catherine E. Stoddart (Manchester Municipal School of Art). (No. 1698.)

Highly commended :

Miss Esther May Stewart (Hastings School of Art). (No. 1308.)

Miss Janet I. Campbell (Hornsey School of Art). (No. 1414.)

Commended :

Miss Helvetia Forshaw (Liverpool School of Art). (No. 1810.)

Miss Margaret H. McColl (Glasgow School of Art). (No. 507.)

SUB-SECTION 4. Design for a seamless Axminster Square suitable for a drawing room or boudoir. Prizes offered by the Carpet Manufacturing Co., Ltd.

As a collection the designs shewed an improvement upon last year, but the judges are of opinion that no single design was of sufficient merit to earn the full award. They, therefore, consider that the prize of £30 should be divided equally between

Joe Moore, (International Correspondence Schools. Ltd., W.C.2). (No. 593), and

Cyril Astle (Kidderminster School of Art). (No. 1244.) No. 1245 by this student is of equal merit with No. 1244 in regard to drawing, but is incomplete owing to the absence of corners.

A Royal Society of Arts Prize of £10 is also awarded to Miss Margaret E. Hays (The Mythe, Bognor). (Nos. 352 to 354.)

The design of this student was in itself of outstanding merit, but the subject was not very appropriate to carpets.

A Royal Society of Arts Prize of £5 is awarded to Harold John Watkins (144, Park Street, Kidderminster). (No. 472.)

An Owen Jones Medal is awarded to Cyril Astle (Kidderminster School of Art). (No. 1244.)

Highly commended :

Walter Shepherd (159, Chester Road, Kidderminster). (Nos. 250 to 252.)

Walter Frances Mallard ("Lyndale," Radford Avenue, Kidderminster). (No. 127.)

Walter Taylor (8, Manor Road, S.W.20). (No. 218.)

This design would be suitable for a hand-woven carpet.

Commended :

Harry Hall (Halifax School of Art). (No. 1627.)

Ralph Hill (Kidderminster School of Art). (No. 1248.)

The general balance and colour scheme are good in both these designs.

SUB-SECTION 5. *Designs for Linen Table Damask. Prizes offered by Messrs. Hay and Robertson, Ltd.*

The awards are as follows :—

The First Prize of £15 to Miss Violet Pym (Taunton School of Art). (No. 1447.)

The Second Prize of £10 to Tom Fraser (Lauder Technical School, Dunfermline. (No. 1973.)

Highly commended :

James Clunie (Lauder Technical School, Dunfermline). (No. 1974.)

Phyllis Went (Taunton School of Art). (No. 1449.)

Commended :

Marjory Price (Liverpool School of Art). (No. 1825.)

SUB-SECTION 6. *A set of at least six designs for Printed Dress Goods; a set of at least three designs for Printed Furnishings, and a set of at least three designs for Woven Dress Goods. A Travelling Studentship of £75 offered by the Tootal Broadhurst Lee Company, Ltd.*

The Travelling Studentship of £75, offered by the Tootal Broadhurst Lee Company, Ltd., and an Owen Jones Medal, are awarded to Miss Sadie Nixon (Slade School of Art), (Nos. 1004 to 1010 and No. 1012), who submitted by far the best set of designs, and showed that she has much more invention than is displayed by any other competitor. There was, however, some lack of attention to execution and detail, even in this set, and this is a point for this student to consider seriously.

The following awards are also made :—

A Royal Society of Arts Prize of £10 to Miss Evelyn Stiles (Hammersmith School of Arts and Crafts). (Nos. 2078 to 2080.) This student shows great promise of originality as a designer and certain care in execution, but colour might be improved in the direction of brightness and freshness.

A Royal Society of Arts Prize of £5 to Miss Phyllis Nixon (Croydon School of Art). (Nos. 2041, 2042, 2046, 2049.) This student shows promise and her execution is good.

Highly commended :

Miss Ivy Collyer (Croydon School of Art). (Nos. 1994, 1996, 1997, 1998, 2000, 2005, 2011, 2012.)

Commended :

Miss Frances Maud Dickens (City School of Art, Liverpool). (Nos. 1796 and 1798.)

Miss Esmé Caton (Croydon School of Art). (Nos. 1981, 1982, 1986, 1988, 1989, 1992.)

Miss Mary G. Elliott (Edinburgh College of Art). (Nos. 1528, 1529, 1531, 1556.)

Miss Margaret H. S. Arnot (Edinburgh College of Art). (Nos. 1526, 1527, 1540, 1543, 1546, 1550, 1551.)

Miss Phyllis Donaldson (Royal College of Art). (Nos. 2205, 2206, 2207, 2212, 2213, 2218.)

The average of the competitors commended is fairly high, and this distinction is given in each case on the merit of *some* of the work in the set, though other designs may not be considered worthy of award.

On the whole, colour seems better and design more ingenious than in previous years, though some examples still show a lack of appreciation of the needs of fashion and of fitness for purpose. These points cannot be too strongly insisted on, and great attention should always be given to them by both the student and the teacher.

SECTION III.—FURNITURE.

General.

The judges have to confess to some disappointment with the standard of work submitted in this section. After due allowance is made for the fact that the drawings are those of students and young men rather than those of experienced designers, the level of attainment is still lower than might have been expected.

For this reason (in accordance with the rules governing the competition), the judges have reluctantly advised the Council to award prizes of less value than those offered in each sub-section.

The draughtsmanship was, on the whole, good, though it was noticeable that when colouring their designs many of the competitors adopted distressing purple effects.

The general criticism of the designs is that few of them (from internal evidence) appear to be the work of students who approach their subject in a really scholarly way. It is probable that very few of the competitors have made an exhaustive study of any single style in order to gain some appreciation of the general principles underlying furniture design.

In modern furniture the architectural features as beloved of the Renaissance designers are entirely dispensed with. In the Paris Exhibition of 1925, for example, it was difficult to find a cornice moulding of any kind. But it is certain that seventy-five per cent. of the students who submitted designs in this competition would have done better work if they had followed the example of the illustrious 18th century cabinet makers and made a close study of the proportions and refinements of the classic orders.

Lest this should be misunderstood, it is not the absence of bases, columns and entablatures that the judges regret, but a lack of that fine sense of proportion without which no furniture designer can hope to achieve permanent success.

SUB-SECTION 1. *Prizes offered by Messrs. W. Turner, Lord and Co., for designs for Furniture in Walnut of Queen Anne Period suitable for a Dressing Room or Dining Room (30ft. x 20ft. x 12ft.).*

The awards are as follows :—

Prize of £5 5s. to D. McCallum Grassie, 14, Blythswood Terrace, Sandy Road, Renfrew. (No. 1079.)

Prize of £3 3s. to Ernest E. Tucker, Blackheath, Lee, Lewisham and Greenwich School of Art and Crafts. (Nos. 205 to 209.)

Prize of £3 3s. to William F. Payne, Bath Art School, Evening Classes. (No. 738.)

Highly commended :

Patrick Casey, Barnstaple School of Science and Art. (Nos. 1108 and 1109.)

Commended :

Cyril L. White, 38, Carnarvon Street, Netherfield, Notts. (Nos. 228 to 230.)

The Competitors appear to have been in some doubt as to whether they should adhere closely to the recognised details of the style or to develop Queen Anne designs in accordance with modern requirements. The chief criticism of the Judges was of a lack of appreciation of the flat contours of mouldings in cross-branded work, and of the subtle beauty of the cabriole leg.

Mr. D. McCallum Grassie, who was awarded the first prize, has a knowledge of present-day requirements and exercises some skill in the use of veneers. Mr. William Francis Payne shows some originality, coupled with appreciation of the style, but his construction at the top of the sideboard pedestals is ill-considered, while the break at the top corners of his mantelpiece destroys the restfulness of the design, without adding anything to its beauty. Mr. Ernest E. Tucker submits a well-considered design, though his dining table is not definitely of the Queen Anne type. Mr. Patrick Casey has tried to get more out of the Queen Anne style than there is in it. The line of his leg is good, and the foot particularly pleasant, but his mirror and the 3ft. cabinet mar a scheme which otherwise has much to commend it. His coloured perspective was well executed.

SUB-SECTION 2. *Prizes offered by Messrs. Green and Abbott, Ltd., for designs for Inlaid Furniture suitable for a Bedroom (30ft. x 20ft. x 12ft.).*

The awards are as follows :—

Prize of £5 5s. to Cyril L. White, 38, Carnarvon Street, Netherfield, Notts. (Nos. 231 to 233.)

Prize of £3 3s. to Thomas Lees, 5, Russell Cottages, Broadway, Worcestershire. (No. 106.)

Prize of £2 2s. to Douglas Luscombe Hadden, High Wycombe Technical Institute. (No. 1346.)

Commended :

Louis Jozev Smith, 49, High Road, Woodford Wells, Essex. (Nos. 756 to 760.)

The prize in this section was offered for " designs for inlaid furniture suitable for a Bedroom." The specification might have been a little more precise. Inlaid furniture suitable for a bedroom might describe a very quiet and restrained treatment with a minimum of inlaid lines and bandings, or on the other hand a suite characterised by a large amount of marquetry in coloured woods of a type which has recently been rendered popular by enterprising manufacturers.

Mr. Cyril Leslie White submitted a thoughtful design which was placed first by the Judges. He is more concerned with proportions and colour treatment than with constructional details, and only obtained the first place by a very narrow margin, chiefly because of this lack of appreciation of construction shown in the plan of his wardrobe.

The work of many other competitors was characterised by a lack of restraint. Strong, violent colour in marquetry should be avoided, natural woods being preferable unless the colour is used with consummate skill.

Mr. Douglas L. Hadden shows originality, and obtained his effects by the skilful use of veneers, rather than by marquetry.

Mr. Thomas Lees sends a drawing which is full of thought, both in the moulded and inlaid detail. His drawing might easily be overlooked because of his dull method of presentation. If he would make a further study of proportion, and then use about a quarter of the amount of detail which he employs here, he might design some interesting furniture.

Mr. Reginald B. Higgs (1238-9), of the Leicester College of Arts and Crafts, sends an interesting design for walnut bedroom furniture, but is not sufficiently original to merit any award. The bedroom suite submitted by Mr. Louis J. Smith shows that he is conversant with the requirements of the trade.

SUB-SECTION 3. *Prizes offered by Messrs. Waring and Gillow, Ltd., for designs for Furniture of a restrained modern style for a Dining Room (24ft. x 16ft. x 10ft. 6in.) or a Bedroom (24ft. x 16ft. x 10ft.).*

The awards are as follows :—

Prize of £5 5s. to William Harper, Newbiggin, Craiglochart Avenue, Slateford Midlothian, Scotland. (No. 357.)

Prize of £3 3s. to John W. Greenwood, Halifax School of Art. (Nos. 1636 and 1637.)

Prize of £3 3s. to William Henry Russell, c/o Mrs. Stanley, Leamington Road, Broadway, Worcestershire. (No. 613.)

Commended :

Cyril L. White, 38, Carnarvon Street, Netherfield, Notts. (Nos. 234 and 235.)

The emphasis in this specification was on restraint and modernity, and very few of the designs submitted possessed both characteristics. Perhaps the only one which exhibited both these traits was by Mr. William Harper, to whom the first prize was awarded. The furniture by Mr. William H. Russell was characterised by a nice proportion. The judges expressed the view that this Competition, concerning itself as it does with the kind of furniture which is needed for every-day trade, should have produced a better set of drawings. One or two of the competitors have endeavoured to escape the difficulties presented by the design of the 6ft. wardrobe by including two smaller ones of about 3ft. 9in. or 4ft. wide.

This is an easy way out of the problem, and not a very practical one. The 4ft. robe would not be large enough for the lady's requirements, and in a house with a bedroom 24ft. by 16ft., the gentleman would probably enjoy the amenities of a dressing room.

SUB-SECTION 4. *Prizes offered by Messrs. Frederick Tibbenham, Ltd., for design for Decorated Furniture painted in Colour, with Figure Subjects.*

The following award is made :—

A Prize of £5 5s. to Cyril L. White, 38, Carnarvon Street, Netherfield, Notts. (No. 236.)

The bedroom furniture submitted by Mr. Cyril L. White is modern in conception, though his treatment of the figure leaves a good deal to be desired.

Mr. Harold Town (468), of 4, Union Street, Bedford, submitted a very "jazzy" scheme. He appears to have enjoyed working this out, but the figure subjects vary in scale on the different pieces, and are subordinated to the violent diagonal lines and the strong colour in the rather insistent triangles of colour.

Mr. Stanley G. Gilbert (561), c/o Mrs. Stanley, Leamington Road, Broadway, designs a music cabinet which is very pleasant in colour, but in a competition where insistence is laid on a figure subject he could not hope to receive consideration. He has evidently made no extensive study of that type of draughtsmanship.

SECTION IV. BOOK PRODUCTION.

The title-pages and pages of text show a very marked improvement over those of last year and the year before.

Many of the title-pages were of great merit, and it was noticeable that those which were considered by the Judges to be best, were very plain and simple in design and arrangement. Certain specimens also showed marked originality without in any way being over decorative or grotesque.

The illustrations on the whole were indifferent, those in colour particularly so. A few of the black and white illustrations showed reasonable merit, but there was nothing very outstanding either in technique or draughtsmanship. The illustrations in colour were very poor. The Judges were disappointed with these exhibits, and trust that an improvement in quality may be shown at the next Competition.

SUB-SECTION 1. *A Title-page set from type, with or without decoration. The actual wording to be as in either or both of the following :*

(a) *The Spirit of Man. Published by Messrs. Longmans, Green & Co., Ltd.*

The awards are as follows :—

A Prize of £5 to Peter Carruthers, 6, Hughenden Road, Horfield, Bristol. (No. 879.)

Highly commended :

Robert Leslie Eastwood, Manchester College of Technology. (No. 313.)

Reginald George Cartmel, London School of Printing and Kindred Trades, Stamford Street, S.E. (No. 894.)

Kenneth Guy Scrutton, London School of Printing and Kindred Trades. (No. 2222.)

Commended :

Frederick George O. Busby, London School of Printing and Kindred Trades
(No. 12.)

William Henry George Adams, London School of Printing and Kindred Trades.
(No. 255.)

(b) *The Oxford Book of English Verse. Published by the Clarendon Press.*

The awards are as follows :—

A Prize of £10 and an Owen Jones Medal to Reginald George Cartmel, London
School of Printing and Kindred Trades. (No. 897.)

Highly commended :

Albert Smith, 209, Galton Road, Beaswood, Birmingham. (No. 751.)

Eric Wood, Bradford College of Art. (No. 1327.)

Kenneth Guy Scrutton, London School of Printing and Kindred Trades.
(No. 2221).

Commended :

George E. Imberg, London School of Printing and Kindred Trades. (No. 966).

Thomas Stanley Martin, London School of Printing and Kindred Trades.
(No. 987.)

SUB-SECTION 2. *Three pages of Text (Demy Octavo) from The Spirit of Man.*

The awards are as follows :—

A Prize of £10 to Reginald George Cartmel, London School of Printing and
Kindred Trades. (No. 899.)

Highly commended :

Walrond J. Hay, London School of Printing and Kindred Trades. (No. 1259.)

Commended :

Frederick A. Horn, 170, Cliffe Road, Otley Road, Bradford. (No. 371.)

Thomas Stanley Martin, London School of Printing and Kindred Trades.
(No. 990.)

SUB-SECTION 3. *An original line illustration, which may be a woodcut, suitable for inclusion in a book printed as the sample page (Crown Quarto), supplied by the Society, the choice of subject being left to the Competitor.*

The awards are as follows :—

A Prize of £5 5s. to each of the following :

John Yunge-Bateman, Heatherley School of Fine Art, 75, Newman Street, W.1.
(No. 1131.)

Miss Barbara Nicholson, Southend Municipal School of Arts and Crafts. (No.
1502.)

Edgar H. Grosvenor, Liverpool City School of Art. (No. 1812.)

Highly commended :

Miss Eileen Le M. Spilsbury, Leeds College of Art. (No. 1753.)

Commended :

A. Stewart Hunt Mills, 1, Holland Road, W.14. (No. 979.)

Miss Joyce Davies, Liverpool City School of Art. (Nos. 1861 and 1862.)

John E. Hanes, Battersea Polytechnic School of Art and Crafts. (No. 1950.)

SUB-SECTION 4. *An original illustration in flat colours, suitable for inclusion in a book printed as the sample page (Crown Quarto), supplied by the Society, the choice of subject being left to the Competitor.*

The following award is made :

Highly commended :

Miss Joan Ivory Packham, 27, Blenheim Park Road, South Croydon. (No. 2067.)

SUB-SECTION 5. *A case for a binding in either cloth or leather (Demy Octavo), for The Spirit of Man.*

The awards are as follows :

Highly commended :

Miss Mary G. Gibson, 52, Waterloo Road, Wolverhampton. (No. 672.)

Commended :

Arthur Gee, Leicester College of Art. (No. 1220.)

SECTION V.—POTTERY AND GLASS.

The very large increase in the number of designs submitted in the pottery Section this year is most encouraging and a source of gratification to the Committee. The standard of work was well maintained and more appreciation of material was shown than in former years, but in some cases these points are still lacking and again the prevailing tendency is towards over-elaboration.

Owing to the necessity of limiting the number of designs for exhibition, the judges had to reject a considerable number which might well have been shown had the space been available.

A large number of Junior Students from the Art Schools submitted designs in this section, and whilst most of them were very good, considering the ages of the Students, the drawings and designs in many cases were immature. The colouring generally was fresh and good, especially in the designs submitted for hand-painted decorations.

There was, in some cases, too much evidence of school influence in the designs submitted, thus robbing the work of the students of freshness and originality. This was particularly noticeable in the designs from Sheffield Art School. This influence of the school is more or less inevitable, but it should be guarded against so as not to become too pronounced.

China.

SUB-SECTION 1. *A Cup and Saucer, Cream Jug, and Bread and Butter Plate with suitable decoration.*

The awards are as follows :—

A Prize of £10 10s. 4d. Ernest Turner Woolrich, Burslem School of Art. (No. 830.)

Commended :

Mrs. Nellie Edwards, 48, Etruscan Street, Etruria, Stoke-on-Trent. (No. 322-325.)

Miss Phyllis Hand, School of Art, Sutherland Institute, Longton. (No. 688.)

Miss Millicent J. Taplin, Hanley School of Art. (No. 1645.)

Mr. Woolrich's shapes were well designed and the drawing well executed, but the handle of the Cream Jug was rather weak, and would have been better had it been brought further down on to the jug.

In design No. 688, the shape of the cup was spoiled by having the lip slightly pinched in.

In design No. 1645 the judges felt that the design was spoiled by the "grassy" border, which was too fussy and restless. The shape of the plate was good and the adaptation of the main border to the shape was excellent.

Designs Nos. 322-5 shewed good brush work and colouring, but the handles were weak, particularly in those of the Bread and Butter plate, which were more suggestive of metal than pottery.

SUB-SECTION 2. A simple decoration on a Cup and Saucer shaped as in a sketch supplied by the Society.

The awards are as follows :—

A Prize of £5 5s. to each of the following :

Frederick Gerald Clay, School of Art, Sutherland Institute, Longton. (No. 289)

John Buchanan, City of Oxford School of Art. (No. 1281.)

Commended :

Joseph Middleton, Burslem School of Art, Junior Department. (No. 1163.)

Arthur Noel Gredington, Newcastle-under-Lyme School of Art. (Nos. 1177 and 1178.)

Miss Doris Parton, Hanley School of Art. (No. 1662.)

The design No. 1163 was commended for its good design and simple brush work, whilst Nos. 1177-8 were selected for their suitable design for gold and blue decoration. Work in this sub-section was exceedingly neat, well balanced generally and carefully executed.

Whilst selecting No. 1281 for a prize, the judges were unable to adjudge any award to the other designs submitted by this student owing to the decorations being somewhat overloaded.

Earthenware.

SUB-SECTION 3. A Dinner Plate and Vegetable Dish of simple design, with suitable decoration.

The awards are as follows :—

A Prize of £10 10s. to Frederick Gerald Clay, School of Art, Sutherland Institute, Longton. (No. 300).

Highly commended :

Miss Millicent J. Taplin, Hanley School of Art. (No. 1649.)

Commended :

Victor H. W. Grimes, Burslem School of Art, Junior Department. (No. 1151.)

Miss May Mountford, Hanley School of Art. (No. 1656.)

Miss Doris Parton, Hanley School of Art. (No. 1663.)

The prize-winning design was well thought out and suitable for its purpose, the colouring was good, and the drawing very carefully executed.

In this sub-section many of the designs shewed a lack of right consideration in the shape of the Vegetable Dish and Cover. In many cases the handles were so slender that they would easily break, and the knobs of such a form as would be easily chipped.

SUB-SECTION 4. *A plain round Bowl, with decoration suitable for either China or Earthenware.*

The awards are as follows :—

A Prize of £5 5s. is awarded to each of the following :

Miss Mavis Durose Woollam, Burslem School of Art, Junior Department. (No. 1157).

Norman Thomas Stephen Hull, Hanley School of Art. (No. 1718.)

Highly commended :

John Buchanan, City of Oxford School of Art. (No. 1284.)

Commended :

Arthur Noel Gredington, Newcastle-under-Lyme School of Art. (No. 1180.)

In this sub-section the shapes submitted were generally simple and good, but many of the designs were not specially suitable for Bowls; in fact they were more suitable for Plates. The designs in this class were perhaps the least satisfactory of any. With regard to the designs in the Pottery sub-sections generally, the judges appreciated the painstaking efforts apparent and the excellence of much of the work submitted, but did not find on this occasion any Student Competitor sufficiently outstanding to warrant the recommendation of the Owen Jones Medal Award.

Glass.

SUB-SECTION 5. *A Service of Glass (i.e., a Wine Glass, a Tumbler and a Decanter), of good form, with or without decoration.*

The awards are as follows :—

Highly commended :

Leslie Price, Wordsley School of Art. (No. 1397.)

Commended :

Albert Elcock, Wordsley School of Art. (No. 1359.)

Charles Howard Husselbee, Wordsley School of Art. (No. 1390.)

SUB-SECTION 6. *A Water Jug, Goblet, and Salad Bowl, with decoration suitable for cutting.*

The following award is made :—

A Prize of £5 5s. to Leonard Green, Wordsley School of Art. (No. 1383.)

SUB SECTION 7. *A Flower Vase or Bowl or 8in. Candlestick.*

The following award is made:—

Highly commended :

Leonard Green, Wordsley School of Art. (No. 1387.)

In the glass sub-sections the designs submitted were disappointing and lacking in originality.

The present fashion for dining room tables is to have small mats and for Table Glass services to be of antique character, in keeping with the polished wood, but it was very marked that none of the designs submitted were of the style the public demand to-day.

In many cases, especially in regard to designs for Candlesticks, the competitors did not pay sufficient importance to the point as to whether they could be produced commercially.

SECTION VI.—MISCELLANEOUS

There was a very large entry in this section, many substantial prizes having been kindly given by various firms.

Taken as a whole the designs showed exceptional originality and merit. It was noteworthy that what were considered to be the best designs were very simple and striking in character, and yet forceful in their appeal. There was a marked improvement in draughtsmanship and execution as compared with former years.

The lay-outs on the whole were somewhat disappointing, as were also the Window Display Pieces. In regard to the latter, it is hoped that next year, if this prize is repeated, fuller instructions can be given to intending Candidates, as apparently many of them missed the point from want of knowledge of the practical use to which the designs were to be put.

It was exceedingly gratifying to note that out of the principal prize winners, quite a number were very young students, whose ages ranged from seventeen to twenty. This, in the opinion of the judges, is a very encouraging feature.

On the whole the designs in this section must be regarded as very successful.

I.

CADBURY BOURNVILLE TRAVELLING SCHOLARSHIP.

A set of six layouts for press advertisements of Cadbury's Chocolates. The Cadbury Bournville Travelling Scholarship of £50 is awarded to:—

Miss Marjorie Blanche Wilson Fenning, Royal College of Art, S.W. (No. 933).
Commended :

Miss Dorothy Cullen, Royal College of Art, S.W. (Nos. 872 and 873.)

II.

PRIZES OFFERED BY MESSRS. BRYANT & MAY, LTD.

Design for a Poster advertising "Brymay Safety Matches," or "Swan Vestas, the Smoker's Match." The awards are as follows :

For the design showing the most original idea, a First Prize of £10 10s. to Miss Mary Octavia Wingfield, The Castle, Tiverton, Devon. (No. 629.)

A Second Prize of £5 5s. to Miss Marjorie Chatterton, Sheffield College of Arts and Crafts. (No. 2167.)

For the design showing the best draughtsmanship and execution, a First Prize of £10 10s. to Miss May Adele Bilbie, Nottingham School of Art. (No. 1889.)

A Second Prize of £5 5s. to Herbert Wilfred Simons, International Correspondence Schools, Kingsway, W.C. (No. 178.)

Commended :

Arthur Ernest Barbosa, City School of Art, Liverpool. (No. 1776.)

Miss Edith Gwendoline Barclay, City School of Art, Liverpool. (No. 1781.)

Miss Betty V. Batchelor, Chelsea Polytechnic School of Art. (No. 1068.)

Miss Betty Beaumont, Wick Studio, Hove. (No. 1617.)

Leonard G. Stanley, Grosvenor House, Gorway Road, Walsall. (No. 1202.)

James White, City School of Art, Liverpool. (No. 1846.)

III.

PRIZES OFFERED BY MESSRS. J. S. FRY & SONS, LTD.

(1). *Design for a Poster advertising "Breakfast" Cocoa, "Goodwood Chocolates," or "Chocolate Cream Tablets," and employing not less than three and not more than five colours.* The awards are as follows :

The First Prize of £17 10s. to

Geoffrey Leonard Rudd, Nottingham School of Art. (No. 1920.)

The Second Prize of £7 10s. to

Miss Gladys M. Rees, 42, West Hill Road, S.W.18. (No. 817.)

Commended :

Frederick Edward Chambers, Barnstaple School of Science and Art. (No. 1444.)

John T. Hartley, Sheffield College of Arts and Crafts. (No. 2132.)

Miss Joan Hoyle, 86, Oakfield Road, Cannon Hill, Birmingham. (No. 571.)

Miss Violet Sarah Robson, Battersea Polytechnic School of Art. (No. 1937.)

Leonard G. Stanley, Grosvenor House, Gorway Road, Walsall. (No. 1203.)

Frederick Willcocks, Croydon School of Art. (No. 2063.)

(2). *Design for the Cover of a Price List or Works' Magazine associated with, or symbolizing Fry's 1928 Bicentenary.* The awards are as follows :

The First Prize of £17 10s. to

Miss Ivy Evelyn Norman, Nottingham School of Art. (No. 1909.)

The Second Prize of £7 10s. to

Arnold Leslie Verity, City School of Art, Liverpool. (No. 1840.)

Highly commended :

Frederick A. Horn, 170, Cliffe Road, Bradford. (No. 368.)

(3). *Design for a Showcard advertising Fry's Chocolates in lettering, or pictorially.* The awards are as follows :

The First Prize of £17 10s. and the Second Prize of £7 10s. are divided equally between :

James A. Bayman, City School of Art, Liverpool. (No. 1787), and
Eric Bostock Byrd, Cardiff School of Art. (No. 1524.)

Commended :

Harold Hemingway, Rochdale School of Art. (No. 1486.)
Miss Molly Chilton Price, Bath School of Art. (No. 427.)
Henry Isaac Robson, Mr. John Hassall's Studio, Kensington. (No. 601.)
Alexander Leslie Russell, Dundee School of Art. (No. 151.)

IV.

PRIZES OFFERED BY MESSRS. FRYER & CO., (NEELSON), LTD.

(1). *Design for a 4 lb. Decorated Tin Confectionery Package in not more than six colours.* The awards are as follows :

The First Prize of £17 10s. to

Miss Dorothy Cullen, Royal College of Art, S.W. (No. 876.)

The Second Prize of £7 10s. to

Miss Sylvia Paul, City School of Art, Liverpool. (No. 1823.)

Commended :

Miss Edith Gwendoline Barclay, City School of Art, Liverpool. (No. 1782.)
James A. Bayman, City School of Art, Liverpool. (No. 1788.)
Miss Sylvia Paul, City School of Art, Liverpool. (No. 1822.)
Miss Grace Thompson, City School of Art, Liverpool. (No. 1838.)

(2). *Design for a Showcard advertising " Victory V. gums and Lozenges for Cold Journeys, the World's Winter Sweet."* The awards are as follows :

The First Prize of £17 10s. to

Miss Edith Gwendoline Barclay, City School of Art, Liverpool. (No. 1783.)

The Second Prize of £7 10s. to

Miss Doris Elizabeth Gully, Battersea Polytechnic School of Art. (No. 1962.)

Commended :

Frances H. Bramwell, Sheffield College of Arts and Crafts. (No. 2091.)
John Dixon, Bradford College of Art. (No. 1326.)
Miss Helen Marjorie Hettinger, L.C.C. Central School of Arts and Crafts. (No. 347.)
Miss Roma W. Kerfoot, Manchester Municipal School of Art. (No. 1686.)
Miss Sylvia Mary Slade, Margate School of Art. (No. 1195.)
Miss Marjorie M. Trueman, Nottingham School of Art. (No. 1927.)

V.

PRIZE OFFERED BY HENLEY'S TYRE AND RUBBER COMPANY, LTD.

Design for a Poster advertising the Henley Stitchless and Sealed Tennis Ball. The awards are as follows :

The Prize of £50 and an Owen Jones Medal to

Frank Herbert Pavely, L.C.C. Hackney Institute. (No. 143.)

Highly commended :

Michael Flannery, International Correspondence Schools, Ltd., W.C.2. (No. 674.)

Leonard G. Stanley, Grosvenor House, Gorway Road, Walsall. (No. 1204.)

Commended :

Douglas Boden, Brighton School of Art. (No. 26.)

Sidney Vincent Dimond, L.C.C. Camberwell School of Arts and Crafts. (No. 490.)

Miss Margaret H. Tubby, 34, Torrington Park, North Finchley, (No. 204.)

VI.

PRIZES OFFERED BY MESSRS. ROWNTREE & CO., LTD.

Design for a Window Display Piece. The entries for this year's competition were, in the opinion of the judges, a slight improvement on last year's, but did not indicate a thorough grasp of the subject of the competition. Two of the entries were sufficiently outstanding, as ideas, to warrant consideration and consequently the judges awarded consolation prizes as under :

A Prize of £15 is awarded to

Miss Dorothy K. Thick, Bournemouth School of Art. (No. 2185.)

A Prize of £10 to

Miss Mary Emmeline Radford, 28, Francis Street, W.C.1. (No. 2175.)

VII.

PRIZES OFFERED BY THE UNDERGROUND GROUP OF COMPANIES.

(1). *Design for a Poster depicting the easy access to the London Theatres afforded by the Underground Railways.* The awards are as follows :

A First Prize of £10 10s. for draughtsmanship, etc., to Harry Turner, Halifax School of Art. (No. 1620), and

A Second Prize of £5 5s. for an original idea, to Miss Pauline Octavia Legard, 27, The Bolton Studios, S.W.10. (No. 386.)

Highly commended :

Arthur Reginald Harrison, Margate School of Art. (No. 1197.)

Alfred E. Kerr, 12, Deramore Avenue, Belfast. (No. 709.)

Commended

Miss Daphne Barry, Battersea Polytechnic School of Art. (No. 1932.)

Miss Doris Elizabeth Gully, Battersea Polytechnic School of Art. (No. 1963.)

Miss Ivy Evelyn Norman, Nottingham School of Art. (No. 1912.)

Eric Stanley Volz, Hornsey School of Art. (No. 1426.)

(2). *Design for a Poster inviting passengers to do their shopping between the hours of 10 a.m. and 4 p.m.* The awards are as follows :—

For the design showing the most original idea a First Prize of £10 10s. to Miss Katie McDonald, L.C.C. Central School of Arts and Crafts. (No. 126), and

A Second Prize for draughtsmanship, etc., of £5 5s. to Miss Daphne Barry, Battersea Polytechnic School of Art. (No. 1935.)

Commended :

Percy Bamberger, 7, Crescent Drive, Helsby, Cheshire. (No. 23.)

Miss Blanch Hope Osborn, Battersea Polytechnic School of Art. (No. 1939.)

Arthur Lloyd Taylor, 20, Highfield Road, Purley. (No. 385.)

VIII.

PRIZE OFFERED BY MESSRS. HUGON & CO., LTD.

Designs for two sides of a carton for block "Atora" Beef Suet. The awards are as follows :

The Prize of £10 to Fred McDonald, 15, Rokeby Terrace, Heaton, Newcastle-on-Tyne. (No. 142.)

Highly commended :

Horace Frederick Grace, "Glenview," Cavell Road, Billericay. (No. 939.)

Derek Anderson Kelsey, Regent Street Polytechnic, School of Art, W.I. (No. 378.)

Commended :

Miss Phyllis Mary Ladyman, Margate School of Art. (Nos. 1198 and 1199.)

APPENDIX.

The Report on the Competition of Industrial Designs for 1926 contained a complete list of the subscriptions to the Prize and Scholarship Fund for the years 1924-26. This year a great many of the larger prizes have been offered by manufacturing firms for designs for special purposes. In several cases the judges did not consider the work submitted deserving of the full awards. The amounts offered by the firms are given in the list below, and the amounts actually awarded are printed in brackets.

SECTION I.—ARCHITECTURAL DECORATION.

	£	s.	d.
Royal Society of Arts (under the John Stock Trust) (no award) ..	50	0	0
Royal Society of Arts (under the Mulready Trust)	20	0	0
Messrs Baguès, Ltd.	50	0	0
A. W. Martyn, Esq.	25	0	0
Arthur J. Davis, Esq., F.R.I.B.A. (Chairman of the Sectional Committee) (£5)	20	0	0
Messrs. Hailwood and Ackroyd, Ltd.	10	10	0
Messrs. Shuffrey and Co. (no award)	5	5	0
Messrs. Lewis Berger and Sons, Ltd.	60	0	0
	£240	15	0

SECTION II.—TEXTILES.

	£	s.	d.
Messrs. Warner and Sons (£10)	45	0	0
Messrs. Arthur H. Lee and Sons, Ltd.	100	0	0
Messrs. Simpson and Godlee, Ltd.	105	0	0
The Carpet Manufacturing Co., Ltd.	30	0	0
Messrs. Hay and Robertson, Ltd.	25	0	0
The Tootal Broadhurst Lee Company, Ltd.	75	0	0
<i>Donations to the General Prize Fund.</i>			
Messrs. Turnbull and Stockdale	25	0	0
Thomas Muddiman, Esq.	5	5	0
The Weavers' Company	5	5	0
A. F. Kendrick, Esq.	1	1	0
	£416	11	0

SECTION III.—FURNITURE.

	£	s.	d.
Messrs. W. Turner Lord and Co. (£11 11s.)	25	0	0
Messrs. Green and Abbott, Ltd. (£10 10s.)	25	0	0
Messrs. Waring and Gillow, Ltd. (£11 11s.)	25	0	0
Messrs. Frederick Tibbenham, Ltd. (£5 5s.)	25	0	0
<i>Donation to General Prize Fund.</i>			
Sir Bignell G. Elliott, K.B.E.	5	5	0
The Joiners' Company	5	5	0
	£110	10	0

SECTION IV.—BOOK PRODUCTION.

Donations to General Prize Fund.

	£	s.	d.
The Federation of Master Printers	15	15	0
The Master Bookbinders' Association	15	15	0
Messrs. John Dickinson and Co., Ltd.	10	10	0
Messrs. W. H. Smith and Sons, Ltd.	10	10	0

Messrs. Longmans, Green and Co., Ltd.	..	..	..	..	10	0	0
Messrs. Henry Stone and Son, Ltd...	..	..	..	..	10	0	0
Messrs. George Barber	..	..	..	..	5	5	0
Sir John Murray, K.C.V.O.	..	..	..	..	5	0	0
The Stationers' Company	..	..	..	..	4	4	0
The Cambridge University Press	..	..	..	..	2	2	0
Messrs. Hazell, Watson and Viney, Ltd.	..	..	..	..	2	2	0
C. J. L'Estrange, Esq.	..	..	..	..	2	2	0
James MacLehose, Esq., LL.D., F.S.A.	..	..	..	..	2	2	0
The Medici Society, Ltd.	..	..	..	..	2	2	0
Messrs. Waterlow and Sons, Ltd.	..	..	..	..	2	2	0
Messrs. B. T. Batsford, Ltd...	..	..	..	..	1	1	0
Messrs. Chatto and Windus	..	..	..	..	1	1	0
C. T. Jacobi, Esq.	..	..	..	..	1	1	0
Messrs. Robert Rivière and Son, Ltd.	..	..	..	..	1	1	0
Messrs. Hodder and Stoughton, Ltd.	..	..	..	..	1	0	0
					£104 15 0		

SECTION V.—POTTERY AND GLASS.

The Goldsmiths' Company (£47 5s.)	..	..	..	..	£63	0	0
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SECTION VI.—MISCELLANEOUS.

					£	s.	d.
Messrs. Cadbury Brothers, Ltd.	..	..	..	..	50	0	0
Messrs. Bryant and May, Ltd.	..	..	..	..	31	10	0
Messrs. J. S. Fry and Sons, Ltd.	..	..	..	..	75	0	0
Messrs. Fryer and Co. (Nelson), Ltd.	..	..	..	..	50	0	0
Henley's Tyre and Rubber Company, Ltd.	..	..	..	..	50	0	0
Messrs. Rowntree and Co., Ltd. (£25)	..	..	..	..	40	0	0
The Underground Group of Companies	..	..	..	..	31	10	0
Messrs. Hugon and Co., Ltd.	..	..	..	..	10	0	0
					£338 0 0		

GRAND TOTAL £1210 11 0

NOTES ON BOOKS.

HYDROLOGY AND GROUND WATER. A practical Text-book for all Those who Deal with the Control of Water. By J. M. Lacey. London: Crosby, Lockwood and Son. 12s. 6d. net.

We have here, in the compass of 160 + viii pages, a well arranged comprehensive, but concisely written, handbook, which includes forty-one illustrations in the text.

Chapters I to III deal fundamentally and thoughtfully with the rainfall question, the first and vital aspect; rain being the most obvious, and most easily gauged, aspect of water in the usual course of circulation. The British Isles are situated unfavourably, or "in the region of maximum rainfall of the north temperate zone" for profound studies on the incidence of the rainfall, p. 15; and typical or exemplar

instances are consequently taken in some cases from distant regions. The hydrographic basin in its various aspects of reception, shed, evaporation, flow, and relation to capacity or position comes next as far as detail is concerned, and on p. 19 we find an instructive study of the Mediterranean Sea from this standpoint; evaporation being so excessive that "except for an occasional outward current, there is almost a constant current into it."

Porous strata are dealt with on pp. 32-39, on a mathematical basis founded upon the size of the particles, and this leads on to the general theory and practice as regards springs. From this we pass on to wells, pp. 94-154, which are considered from many points of view and with numerous illustrations.

Here we have a good example of an admirable text book, uniting theory and practice, with mathematics in moderation.

COCA CULTIVATION IN PERU.

The alkaloid coca plant is found on the Eastern slopes of the Andes, where it grows wild in luxuriant abundance, and on account of the stimulating qualities it is known to possess it is much in demand by the Indians of the entire Andean plateau. The leaf, in addition to being harvested in its natural state, is also extensively cultivated in Peru, particularly in the Department of Huanuco, and the Province of La Convencion in the southern part of the Republic. The article is of such common use amongst the Indians, and is so indispensable to their needs, that it constitutes an important article of commerce in all the sierra region, and is often employed as a medium of barter or exchange. Moreover, the market is an unfailing one, and as its use is so universal, it has become a common practice, writes H.M. Consul at Callao, to regard it as a barometer of business prosperity in the Andean region. The amount of the annual production of this leaf in Peru is uncertain, but it probably represents about 5,000 tons. A small amount of the plant is diverted to the manufacture of cocaine, which is undertaken in factories established at Huanuco and Trujillo. In 1925, 621 kilos. of cocaine were exported, valued at £p.11,191, and 216 tons of dried coca leaves, valued at £p.19,780, the coca leaves going to Chile and the cocaine to Japan and Germany.

GENERAL NOTE.

REPORT OF THE FUEL RESEARCH BOARD FOR THE YEAR 1926 :—The report of the Fuel Research Board for 1926 contains a review of the more outstanding events connected with their work and deals with the progress of the Physical and Chemical Survey of the National Coal Resources, which is gradually extending its activities to new areas, and of the study of methods of sampling and analysis of coal. The experimental work on low temperature carbonisation of coal proceeded throughout the year, and satisfactory progress was made. The arrangements made with the Gas Light and Coke Co. for further development on a commercial scale of the plant designed at H.M. Fuel Research Station are described.

The report of the Director of Fuel Research for the same period gives fuller details of the work in hand and the progress made; special attention may be drawn to the work on low temperature carbonisation, the production of oil from coal by methods other than carbonisation, and the study of metallurgical coke. The Report, price 1s. 3d., can be obtained from H.M. Stationery Office, Adastral House, Kingsway, W.C. 2.

JOURNAL OF THE ROYAL SOCIETY OF ARTS

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FRIDAY, SEPTEMBER 9th, 1927.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2.)

NOTICES.

INDIAN SECTION COMMITTEE.

The list of members of the Indian Section Committee is as follows :—

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Sir Philip Magnus, Bt. (Chairman of the Council).
Sir Charles H. Armstrong.
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W. Perry, B.A. (Secretary).

PROCEEDINGS OF THE SOCIETY.

CANTOR LECTURES.

PHOTO-ELASTIC MEASUREMENTS OF STRESS DISTRIBUTION.

By PROFESSOR E. G. COKER, M.A., D.Sc., F.R.S., M.INST.C.E.,
of UNIVERSITY COLLEGE, LONDON.

LECTURE I.—*Delivered February 14th, 1927.*

INTRODUCTION.

The design and construction of machines and structures usually involve the consideration of a great number of connected problems in order to produce a successful result, and the fact that the ability to achieve success in this field is widely distributed rather tends to conceal from those who are not especially interested, what a vast amount of skill, experience and scientific knowledge must be brought to bear on a problem like the construction of a motor car, or in another direction, the design of a bridge of great span.

In both of these very different cases there are conditions to be solved which have more or less common features.

In the motor car the dynamic effect of pistons, which start from rest at each end of the stroke and attain great velocities near the centre of their path, has to be carefully analysed and provided for, while in a great bridge the moving load due to wind pressure in a storm is one of the most serious elements in the designer's problem.

Whatever may be the diverse elements to be considered, the engineer is bound to provide a structure which will be both safe and useful, and he must, therefore, design in such a manner that no reasonable contingency will produce an overload sufficient to cause failure in the material used. The properties of engineering materials and their usefulness to resist the loads which may come upon them is therefore a subject of prime importance to all engaged in constructional work, and it is not surprising that every aspect of the production of materials, their manufacture into suitable shapes, their chemical and physical

constitution, and many like matters, have been studied with minute care by all civilised races.

One of the important sub-divisions in this field is a knowledge of the distribution of the internal stress in materials produced by loading, and it may at first glance appear to be quite a simple matter to determine this, since in most cases of engineering practice we try to get as uniform conditions of tension, compression, and shear stress, as possible, and therefore if the conditions of failure for these cases are known it seems a simple matter to keep within safe limits of stress and to avoid all difficulty.

This impression is quickly dispelled, however, if we take one of the simplest cases, say, of a nut and bolt used for connecting two pieces together. In the main body of the bolt there will be simple tension stress f , which can be easily calculated when we know the total load P and the cross-sectional area A by the obviously simple rule that $P=Af$, but at each end disturbing circumstances arise, one due to the bolt head and the other due to the screw thread, which latter, by universal consent, is the most convenient way to attach the nut to the bolt.

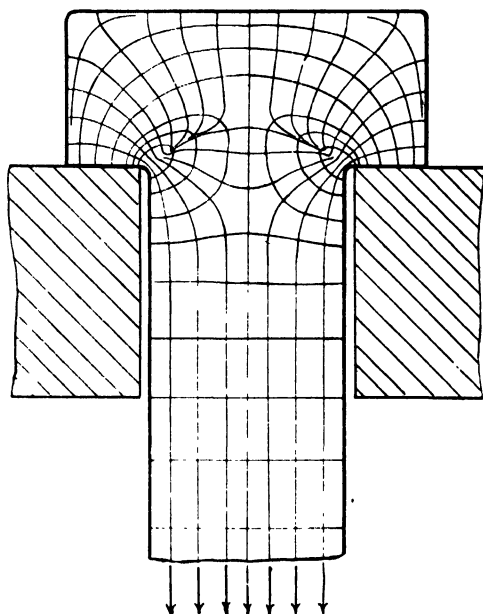


FIG. 1.—Lines of principal stress in the head of a bolt.

Although the head of the bolt increases the cross-sectional area, its effect is to increase greatly the stress at the surface of the bolt where it joins the head. The lines of stress crowd together at these places as indicated in Fig. 1. Some idea of this increase of stress at this section AB is obtained by a curve CDE , Fig. 2, in which the ordinates measured from the base AB indicate the stress intensities which may be compared with the uniform stress f in the main body.

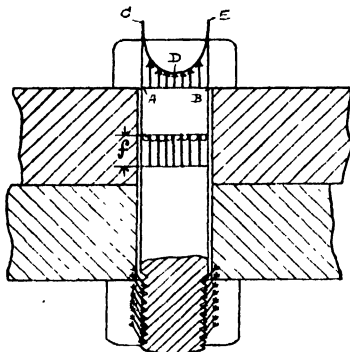


FIG. 2.—Stress distribution in a bolt.

The smaller the radii of the fillets connecting the body of the bolt to the head at A and B, the greater is the stress at the extremities, and it is therefore not surprising that occasionally the head of a bolt or a rivet head flies off due to a crack in the material which begins at A or B and extends right across the area.

If now we take the screw thread at the other end, it is much easier to see that these sharp indentations in the material must increase the stress in it very largely, not so much on account of the decrease of cross section, but because of the series of notches which have been cut in it and on which the nut presses in an inclined direction somewhat as indicated by the arrows in the lower part of Fig. 2.

When the nut is screwed up the stress at and near the bottom of the notch is very large as compared with the central part of the bolt, and, as everyone is aware, it is only too easy to strip off the threads of a bolt when screwing up a nut with a spanner, even although the ultimate tenacity of the material in tension is 30 tons or more per square inch. What the stresses are which actually come upon both nut and bolt at the screw thread it is surprisingly difficult to say, and possibly no one knows very accurately. It should not, however, be a matter of indifference, on the ground that we get along well enough without knowing, and this was impressed very clearly on the lecturer some years ago as a passenger in a main line express which came to a standstill, miles away from a station, and had to be laboriously diverted to a side line and ignominiously hauled to the next station for the simple and sufficient reason that one bolt of an eccentric had stripped its thread and had, for the time being, disabled the locomotive completely.

If such an apparently simple case of stress distribution as a bolt presents such difficult problems, it is a fair inference that the majority of cases which arise for consideration are far from easy, and experience confirms this.

All machines and structures present most difficult problems for solution, but, fortunately, most engineers have a gift for combining scientific knowledge with a great fund of practical experience, and as a result failures due to faulty construction and design are few in number and the general public is extraordinarily well served.

FUNDAMENTAL PRINCIPLES OF PHOTO-ELASTICITY AND THEIR APPLICATION TO THE MEASUREMENT OF STRESS.

Having now in some small measure outlined the nature of the problems of stress distribution and its measurement, we must now consider the scientific means at our disposal. In a former series of Cantor Lectures* some of the salient features were described of a method of investigation often used by engineers to determine the stress in a body by measurements of its minute changes of shape and its surface.

It is not the purpose of the present course of lectures to go into this branch of experimental investigation, interesting and valuable as it is, nor is it necessary here to give any account of the vast store of knowledge which purely mathematical processes give us.

We are only concerned here with a method of stress measurement which analyses actual pictures of stress distribution produced in transparent bodies when they are loaded and looked at in polarized light. In order to avoid reference to some preliminary information which was given in the Cantor Lectures referred to above, it may be useful to say that, although we are not quite certain what light really is, it will not lead us into any serious error if we regard plane polarized light as a wave motion transverse to the direction of the beam with the oscillations all taking place in one plane.

Looking endways on to an ordinary beam, we may imagine the vibrations as occurring in every transverse direction, as shown in the left hand of Fig. 3.

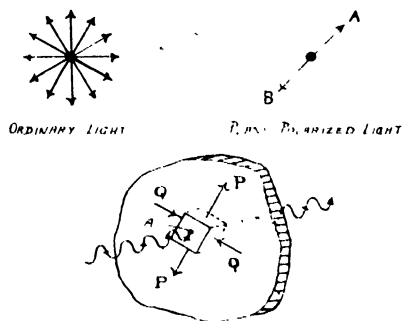


FIG. 3.—Wave motions of light.

We say that a beam of light is plane polarized if we can make all the vibrations occur in one plane, as indicated on the right hand of the same figure. So far as our eyes are concerned there seems to be no difference at all, but this simple form of light wave enables us to see the stresses in transparent bodies as coloured pictures, which are just as beautiful, perhaps even finer, than any picture ever painted.

* "The Measurement of Stresses in Materials and Structures," by E. G. Coker, Royal Society of Arts, December, 1913.

Let this beam pass normally through a transparent plate, which is under such a stress at the point A that this can be represented by a pair of normal stresses P and Q, Fig. 3, acting on the sides of an element with end faces of rectangular or square form. We find that in general the beam is broken up into two parts, one of which vibrates in the direction of the P stress and the other in the direction of the Q stress. The light which comes through is, therefore, a mixture of two beams of plane polarized light vibrating at right angles to one another. It is also found that one beam is retarded proportionally to the stress P and the other proportionally to the stress Q. To the eye the beam looks exactly the same as it did before it passed through the plate, but as we have practically no perception of polarization, this is not to be wondered at.

In order to turn these two separate beams to useful account, a Nicol's prism is interposed which has the useful property of allowing polarized light to pass through it, provided its transverse vibrations correspond to its principal plane.

Now, although in general neither wave is in the right direction to do this, yet a component part will go through and the other part will be rejected. The components of each wave which pass through the analysing Nicol are, therefore, in the same plane, while they still retain the amount of retardation caused by the respective stresses P and Q, and hence we have a relative retardation R which is proportional to P-Q, and also depends on the optical character of the plate itself and its thickness T. We may therefore represent the effect produced by the simple relation

$$R = C (P - Q) T.$$

where C is an optical constant of the material used.

This is the fundamental law on which we depend for obtaining the condition of stress at any point in a plate. For many purposes it is not in exactly the form in which we should prefer it, but as will be shown a little later we can actually find from this retardation R all the requisite information as to the state of stress at any point of a plate under load in its own plane.

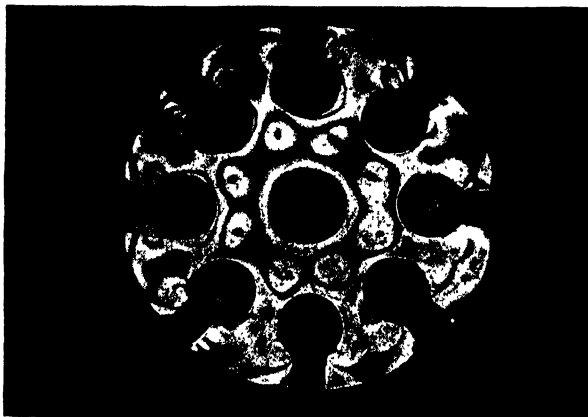


FIG. 4.—An annular ring loaded radially by eight bolts inserted in slots at the outer edge.

Before considering this in detail it may be useful to see what this law means when translated into the form of a colour picture and a somewhat complicated case is now thrown on the screen, in which a plate, Fig. 4, with a central circular hole is loaded by means of pins inserted in slots, and pulled radially by nearly equal forces applied by a suitable mechanism. As you observe, a though this is a very complicated picture, yet each sector between a pair of radial forces is practically the same as any other like sector, and this we should expect from considerations of symmetry

The reason for the different colours is that we have used white light and the interference effects produced in this way by changes in R proceed in the order of black, white, yellow, red, purple, blue, shading gradually into one another and marking the stress difference ($P - Q$) at every point.

A fairly symmetrical arrangement of black spots is also observable in the central area which tells us that $P - Q = 0$, or $P = Q$, but we cannot say what magnitude each stress is without some further investigation. Both may be zero; on the other hand, each may have a definite stress value.

It is worth while to look into this matter a little more closely, because this result contains within it the germ of a very easy method of determining $P - Q$ at every place.

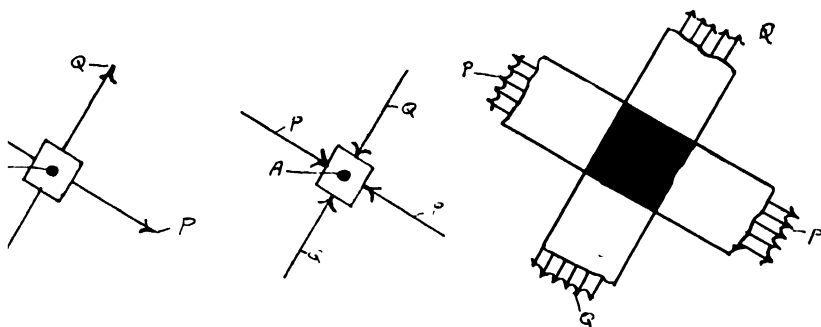


FIG. 5.—Equal like stresses at a point A give a black field.

At a point A, Fig. 5, the black spot may be due to the absence of stress or the presence of equal normal stresses at right angles, either in tension or in compression as indicated. If, however, ($P - Q$) has some value F_1 differing from zero, then it is still possible to produce a black spot at this place by supplying this value F_1 from some external source, and the simplest way to do this is by a separate tension member which is added to the field of view, and is so loaded as to reduce the picture to blackness at this point. This is a better plan than arranging a tension member in the field of view side by side with the object in order to match the colours. It is, in fact, much better to reduce the field to blackness at any given point in order to relieve our eyes from the strain of matching brilliant colours.

PRACTICAL APPARATUS FOR OBTAINING A BEAM OF PLANE POLARIZED LIGHT OR A CIRCULARLY POLARIZED BEAM.

We must now pass on to consider a practical way of producing a beam of plane or of circularly polarized light which does not need the employment of large Nicol's prisms, since these latter are not now obtainable. One of the simplest ways is shown in Fig. 6, in which a thin slice of Iceland spar A is cemented to

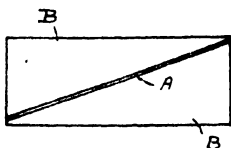


FIG. 6.—A polarizing prism.

a pair of glass wedges, B. Such a prism is found to give a very perfect beam of plane polarized light when ordinary light is passed through it, but it is not an easy matter to make such a prism large enough for our purpose, so that some means must be employed to enlarge the field of view of such a small prism. A way of accomplishing this is shown in Fig. 7, in which a beam of light from a

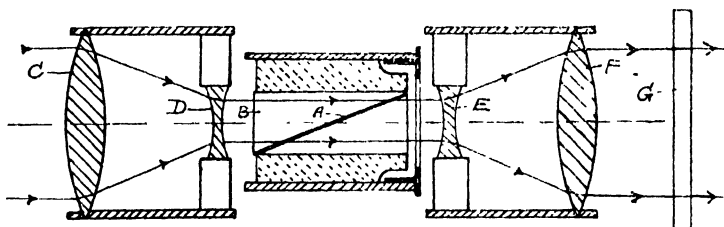


FIG. 7.—Enlarging arrangement for polarizing prism.

lantern is coned down by a convex lens C to pass through a small concave lens D, which renders the beam parallel and small enough to pass through the polarizing prism A B. An inverse arrangement of concave lens E and convex lens F then enlarges the beam and makes it parallel to pass through the specimen G under observation.

As described above, it is found convenient for purposes of measurement to throw an image of both the object G and a stressed tension member T, so that

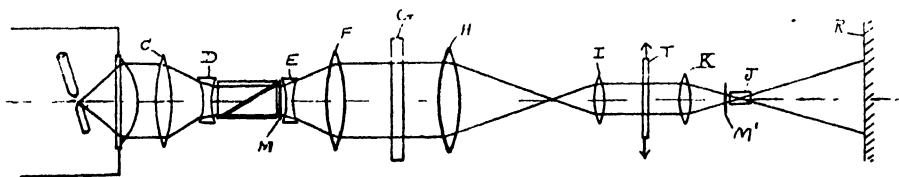


FIG. 8.—General arrangement of polariscope for measurement.

we have to arrange a further system of lenses to accomplish this. A convenient arrangement to effect this is to provide a convex lens H, Fig. 8, to bring the rays to a focus and put in their path another pair of lenses I and K to give a second parallel field in which this loaded tension member is placed. Finally, the beam passes through an analysing prism J of small dimensions before its projection on a screen R.

An important practical point to bear in mind is that a polarized beam will not only detect and register the state of stress in the object G, but will also show the stress in any lens it passes through, and it is therefore necessary that the optical system shall not be defective in this way, otherwise the picture shown will include the stresses in the lenses. When these diagrams are translated

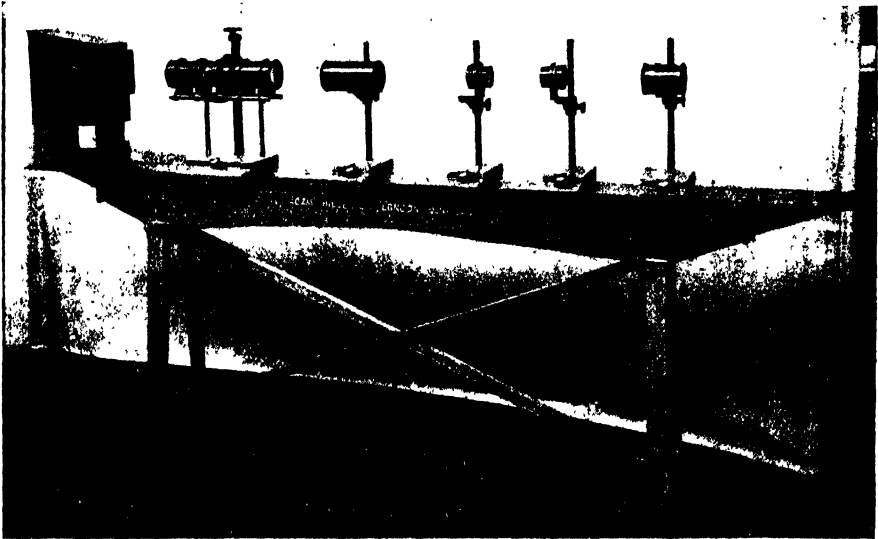


FIG. 9.—Apparatus for photo-elastic experiments designed for use in engineering workshops and laboratories.

into a practical apparatus of use to engineers, it is found convenient to support each part on a separate casting carried on a lathe-bed in such a manner that the central line of the optical system can be adjusted without waste of time. Hence we have a substantial base, with a facing strip on its under side which is drawn up into contact with a flat surface running the whole length of a lathe-bed by an adjusting screw in front of the operator. This brings each central line into one vertical plane and the vertical adjustment of each part is then carried out with reference to a pillar on every casting.

A general view of the whole apparatus is shown in Fig. 9, with an arc lantern in place, and its arrangement will be readily inferred from the line diagrams already described.

Among the important adjuncts to such an apparatus are means for converting a beam of plane polarized light into one polarized circularly. We can get some idea of what this implies if we imagine the polarizing prism A. B, Fig. 6, rotating very rapidly about its optical axis so that the plane of polarization is continually clanging. It is not, however, necessary to resort to such a clumsy mechanical device, since transparent materials exist which, when interposed in the path of the beam will give the same effect in a better way. One of these materials is mica, which possesses the property of splitting up a polarized beam into two parts, and if the thickness and orientation of such a sheet is properly arranged, the relative retardation of these two rays can be made what we please. If a quarter wave length retardation is chosen the beam is then circularly polarized.

We can thus change over from one system to the other by inserting suitable sheets of mica M and M¹, Fig. 8, between which we have circularly polarized light and beyond which in each direction we have it plane polarized.

In using white light, however, we are met with the difficulty that there is a variation in wave length for the different colours, so in practice a thickness of mica is chosen which will give a circular polarization for some constituent at or near the centre of the spectrum and this is found to be a sufficient approximation for the needs of most practical cases. For very accurate work it may, however, be necessary to use light of one wave length and adjust the mica plates to suit this.

INSTRUMENTS FOR MEASURING LOADS AND STRESSES.

It will be at once obvious that a method of ascertaining stress distribution in small models of parts of machines and structures by aid of polarized light involves the design and construction of a large amount of subsidiary apparatus, and more especially so because the general tendency in engineering laboratories is to provide appliances not only of accuracy but of considerable size. There are, in fact, strong reasons in some cases of professional practice for building testing machines of such dimensions, size and strength, that full sized girders, columns, brick piers, and the like, can be tested to destruction. It is a disputed point whether such apparatus is, in general, suitable for laboratory investigations, but this need not concern us, because in any case hardly any testing apparatus available, large or small, is of any use for our photo-elastic measurements. It has to be especially designed and constructed to suit the problem in hand.

A primary necessity is a simple device for measuring accurately a tension load up to, say, 300 pounds, which occupies a very small space, is very light, free from inertia errors, and not likely to get damaged if a specimen breaks suddenly. In general, ordinary spring balances have all the disadvantages mentioned above, and it is therefore necessary to provide some other means which eliminates them. In attempting this we have the useful guidance of the

many successful attempts to eliminate coiled springs from steam engine and other indicators by the use of springy beams or diaphragms in which the deflection is proportional to the load applied, although the internal state of stress varies from point to point usually in a very complicated fashion.

Some of these latter arrangements would, no doubt, be applicable, but a more useful device for our purpose is a complete ring of hardened steel which, when stressed across a diameter, is found to change this latter dimension proportionately to the load applied if the elastic limit of the steel is not exceeded at any point. Although the condition of stress of such a ring is very complex, it is not difficult to design it by optical experiments on transparent models to give a most efficient form for the purpose, usually by varying its thickness from point to point, but whatever form it takes we get essentially a ring forming a case in which is secured some magnifying device which turns the extension between two points into a magnified circular movement and causing a pointer



FIG. 10.—Spring balance for weighing loads up to 160 pounds. Weight of balance 2 ounces.

to register on a dial graduated in suitable units. As an illustration of this Fig. 10 shows such a balance weighing two ounces and capable of measuring loads up to 160 pounds, and very slight changes in the thickness of the ring give a balance registering fractions of an ounce, or, if we desire it, going up to a ton or more. As the extension of the spring is small and the weight of the moving parts minute, we have a robust form of weighing apparatus capable of great use in this work and perhaps of still wider application.

MAPPING LINES OF PRINCIPAL STRESS AND MAXIMUM SHEAR.

In a previous section a method was described of measuring the difference $(P - Q)$ of two stresses acting normally on two planes at right angles, which pass through a line perpendicular to the faces of a plate at some point A. Now it is well known, and is proved in text books on the strength of materials, that, when such a body is loaded in its own plane, there will, at every point, be a state of stress of this kind which is completely specified if P and Q and also their directions θ_P and θ_Q are known, or since $\theta_P = \theta_Q + \frac{\pi}{2}$ when one such direction is known. This information is available from optical experiment alone and is easily found in all such cases.

Let us first consider the directions of these normal or principal stresses. When, as is usual, the polarizing and analysing prisms are set with their principal planes at right angles, there will, in general, be places in the object under load where the directions of principal stress are inclined at the same angles. Light is therefore completely stopped at such points, and hence we find a black point in the projected image there, or, since these are usually distributed along curved lines, the points generally join up to form black bands which show the directions of stress. These bands, or isoclinics as they are termed, are therefore essential to the process of determining the condition of stress at a point, and as we proceed various cases will be considered in detail. It is also known that the directions of maximum shear are inclined at 45° to the directions of principal stress, and therefore the isoclinics give these directions also.

SIMPLE MEASUREMENTS OF STRESS DISTRIBUTION.

It is a piece of good fortune in this method of determining stress that nearly all the important matters we require to know are very easy to measure.

The places of maximum stress, for example, are almost invariably at the outer or inner edges of the member.

Take, for example, the difficult problem of calculating the stress at any form of notch in a tension member. Experimentally this is quite easy, because at any point of the boundary there can only be one stress, viz., along the contour. We have, therefore, only to compare the colour found there with that of a tension member cut from the same plate and stressed to give the same colour. The load on this latter then gives us at once the stress at this place.

As a simple example, which will also be of use later, let us take the case of a tension member one inch wide with two semi-circular notches in it symmetrically placed with reference to its main axis. The distribution at and near these notches is profoundly modified from the state of simple tension in the rest of the specimen and in the interior is rather complex. The maximum stresses, however, are easily found to be at the contour points on the line joining the centres from which the notches are struck, and these stresses are determined

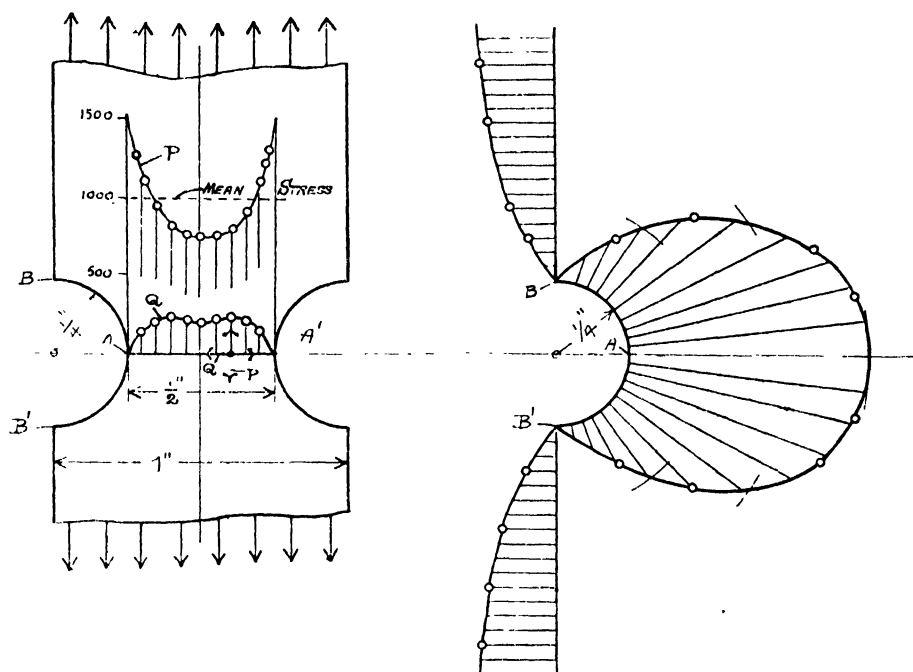


FIG. 11.—The stress distribution in a tension member with two semi-circular notches symmetrically disposed with reference to the line of pull.

without difficulty. If the mean average stress on the specimen at the section A.A¹ is 1,000 pounds per square inch, Fig. 11, we find that the maximum is rather more than 1,500 pounds per square inch. This stress diminishes as we pass round the notch in either direction and become zero at the points B.B¹. Along the straight sides above and below the stress gradually increases from zero until it attains a steady value of 500 pounds per square inch. Any notch can be dealt with in precisely the same way, and as there is a great variety of such forms necessary in engineering practice or used for testing the properties of materials, it is very convenient and instructive to look at pictures of stress of such forms and to make measurements for various practical applications. Moreover, we know from theoretical calculations, as well as from experiment, that in all these cases the stress distributions in steel and other materials are precisely the same.

OBITUARY.

SIR JOHN BENTON, K.C.I.E., M.Inst.C.E.—We regret to record the death on August 29th, at his Eastbourne home, of Sir John Benton, at the age of 77. Born on August 5th, 1850, at Boharm, Banffshire, he was educated privately and at Aberdeen and Edinburgh Universities. He was the first student to enter the Royal Engineering College at Cooper's Hill after its establishment in 1871, and passed

out of the College first of his year in 1873, after winning the distinction of being made a Fellow of the College. Arriving in India Benton was appointed to the irrigation branch of the Public Works Department, and after passing through the various grades of the service retired as Chief Engineer of the Punjab in 1905. He was, however, almost immediately re-appointed by Lord Curzon as Inspector-General of Irrigation for the whole of India, and held this appointment until 1912, when he finally retired from Government service. The name of Sir John Benton, who received the C.I.E. in 1902 and was promoted K.C.I.E. in 1911, is one of the foremost in the annals of irrigational engineering in India and is especially associated with the Upper Swat River Canal, which is carried through the Malakand Hills in a large tunnel, known as the Benton tunnel, and with the "Triple Canal Project" in the Punjab, involving the construction of the Upper Jhelum, Upper Chenab, and Lower Bari Doab Canals at an estimated cost of £5,000,000. This Project, which was sanctioned in 1905 and finally completed in 1917, brought over 1,700,000 acres under irrigation and prepared the way for the great Sutlej Valley scheme. Sir John Benton's Indian career was linked with that of Mr. Sidney Preston, C.I.E., the last of the Stanley engineers, just as Benton was actually the first to enter Cooper's Hill, by the curious fact that the former took over charge from the latter in every grade of the Public Works Department, as Executive Engineer, Superintending Engineer, Chief Engineer, and lastly as Inspector-General of Irrigation. His only son was killed in the Great War.

Sir John Benton had been a Fellow of the Society since 1907, and in 1913 read a paper before the Indian Section on "Irrigation Works in India," for which he was awarded the Society's silver medal.

NOTES ON BOOKS.

THE ARCHITECTURE OF ANCIENT ROME. By William J. Anderson and R. Phœné Spiers. Revised by Thomas Ashby, D.Litt. London: B. T. Batsford, Ltd., 21s. net.

Solid and beautiful monuments of the Roman dominion are dotted about the old world: arches, amphitheatres, aqueducts, bridges, baths and tombs. Moreover, 'tis an ill earthquake brings nobody any good. If the ancient Pompeians had felt the modern solicitude for future generations they would perhaps all have perished with the unflinching calm of their immortal sentry—largely immortalised, alas, by an atrocious picture. Pompeii and Herculaneum were preserved for us by the lava. These towns and Ostia, the port of Rome, have yielded to us invaluable information about the Roman private house.

No more able scholar could have been chosen to revise the work of Messrs. Anderson and Spiers than Dr. Ashby, late of the British School at Rome, who carries the reader through the whole subject from Alpha to Omega, illuminating its technical aspects with frequent touches of social and human interest. After looking at origins he describes the materials and modes of Roman construction. Although the Romans pushed the technique of architecture much further than the Greeks had been able to do, they often failed to recognise a principle which had been ever present in the consciousness of the Hellenic builders, the principle that decoration should not obscure but emphasise structural function. The richness, not to say pomposity, of much of their work was extravagant. Thus in the gorgeous temple of Mars Ultor, built by Augustus, were six columns carrying an entablature but serving no purpose. The columns in the cella of a Greek temple were put there

to support the roof; the Romans, however, knowing the principles of trussed timbers, could roof over a great space without the help of columns, and sometimes, as in the case quoted, only retained these for show.

Some of the Roman buildings were very large. Of the great Pantheon of Hadrian, the authors write that it was in most respects the most remarkable monument ever built, as well as being the largest circular temple. The size of the *Thermae*, too, was astonishing. "The main block of the *Thermae* of Caracalla has an area of 270,000 square feet—greater than either the Houses of Parliament, the Law Courts, or the British Museum." These *Thermae* were raised 20 feet high on an artificial platform, the smoke and heated air from the hypocausts passing under the floors to twelve inch flues in the walls. Such establishments were built by Emperors who wanted to make themselves popular. They were in fact very useful, since they provided for the minds as well as for the bodies of the Romans. There, in addition to bathing and playing games, one could attend readings by philosophers and poets.

The imagination of posterity has been particularly struck by those relics of the Roman imperium which are suggestive of modern ingenuity or which still fulfil the function for which they were built: aqueducts and bridges. The Romans knew that water in a closed pipe finds its own level, but as the cost of the lead which they used was high, and as they did not know how to make pipes of cast-iron, they generally preferred to construct level channels. Photographs are given of the celebrated two-storied aqueduct of Segovia, and of the still more remarkable three-storied one at Nîmes.

Where houses are concerned, it should be noted that the Palatine Hill was the St. James's quarter of Rome, owing to its nearness to the Forum. Augustus bought a house on the Palatine; he left it to his widow, Livia, and it exists to this day. We know a good deal also about a far bigger place close by, built probably by Nero, which was decorated with exquisite paintings, and had the finest pavement of inlaid marble which has come down to us.

Dr. Ashby has a full analysis to make of Pompeian architecture and decoration, both of which show marked Greek influence. The excavations at Ostia, on the other hand, have brought to light houses, some of three and even four floors, to which can be traced many of the characteristics of the Italian domestic architecture of to-day. These houses "have an aspect of solidity and strength which is lacking at Pompeii." In a special sense they are a link between the homes of the ancients and our own homes.

P. B.

BRITISH ENGINEERING TRIUMPH IN EGYPT.

Attention is called in the Report on the Economic and Financial Situation of Egypt by the Commercial Secretary at Cairo, recently published by the Department of Overseas Trade, to an engineering triumph achieved by the firm of Dorman, Long & Co., Ltd., in the construction at Dessouk of a 10-span railway bridge. A contract involving the demolition of the old bridge, the erection of the new one, and the re-capping of thirteen piers was fulfilled in the short space of less than thirteen months, and this in spite of the appalling obstacles occasioned by the coal stoppage. The new bridge is 610 metres long; 3,600 tons of steelwork were used in its construction, and about 300,000 rivets were put into it. The firm had contracted to carry out this work in twelve months, and although the date of its actual completion, viz., January 3rd, 1927, represented 28 days beyond the specified time, this overtime cannot be counted against them, as it was solely due to delay resulting from damage to a pier caused by a collision with river craft. They are

therefore fully entitled to claim that they completed this contract in the time guaranteed by them, which is so short for an undertaking of this nature that, when they secured the order at the end of October, 1925, not only their rivals, but also their friends, were all convinced that it was a sheer impossibility. It therefore redounds all the more to the credit of the firm that they should have so successfully carried out, under the abnormal circumstances engendered by a seven months' coal stoppage, an undertaking which was generally considered to be beyond the power of any firm even under normal conditions. This wonderful engineering feat, affording as it did such signal proof of what a British firm are prepared to do in order to keep their word, created a most favourable impression in Egypt and considerably enhanced British industrial and commercial prestige. At the same time, it completely justified the foresight of the Egyptian Government in entrusting to a British firm an undertaking the early completion of which meant a saving to the railways on the cost of a ferry. This saving more than compensated for the difference in price between the British tender and the Continental offer which was the lowest submitted, but which quoted three years for delivery.

PROGRESS OF ROUMANIA.

In reviewing the years since the war, and especially last year, it is beginning to be possible to form a more accurate idea as to the progress Roumania has made and, under given circumstances, will continue to make, writes the Commercial Secretary to H.M. Legation at Bucharest, in his recent Report to the Department of Overseas Trade.

The fact that the Roumanian Government has consolidated its war debts, and other debts, is in itself a good augury for the future.

Civil administration is continually improving, but still has a long path to travel before perfection is attained. As far as the administration of justice is concerned, there is no question that the delays in dealing with commercial cases are the cause of considerable irritation and hardship to litigants. It is stated, however, that a considerable improvement has been effected by the law passed two years ago for expediting and simplifying the procedure in the commercial courts. Nevertheless, as things are at present, it is certainly advisable on the whole to settle cases out of court. An extension of the Chambers of Commerce Arbitration Courts in the new provinces is also a step in the right direction, and should help to remove some of this congestion.

One of the principal guarantees for the belief that Roumania will continue along the path of progress lies in the character of the population itself. The Roumanian peasant proper, representing over three-quarters of the whole population, is neither quarrelsome nor easily excited. He is a peace-loving individual, hard working, amenable to discipline and can be encouraged to learn. His greatest wish is to be left quietly to till his portion of earth. Risings or upheavals, whether industrial or political, are abhorrent to his nature. His land hunger has been satisfied for the time being by the agrarian reform, and, though conservative, he has been able to show that he was fitted to deal with his new responsibilities. This in itself is an asset to a land which needs peace to consolidate the new portions of the Kingdom, more especially if it is to attract foreign capital, which is essential to develop its wealth of natural resources.

As far as British trade is concerned, and bearing these factors in mind, it may be said that, in regard to dealings with Roumania, the renewal of confidence—temporarily suspended—which has recently been observable, is justified in the eyes of those most qualified to judge.

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FRIDAY, SEPTEMBER 16th, 1927.

*All communications for the Society should be addressed to the Secretary, John Street,
Adelphi, W.C.(2).*

NOTICES.

COMPETITION OF INDUSTRIAL DESIGNS, LOCAL EXHIBITIONS.

The exhibition of industrial designs at the Imperial Institute, which was viewed by about 7,000 visitors, closed on August 31st. Arrangements have been made this year, as in the three previous years, for holding exhibitions of particular sections of designs in provincial industrial centres after the end of the exhibition in London. An exhibition of the designs for pottery and china will accordingly be held at the Burslem School of Art and of the textile designs at the Royal Technical College, Glasgow. Both exhibitions will be open from about the middle of September to the end of the month.

DOMINIONS AND COLONIES SECTION COMMITTEE.

The list of members of the Dominions and Colonies Section Committee is as follows :—

Major Sir Humphrey Leggett, R.E., D.S.O. (Chairman).
Sir Philip Magnus, Bt. (Chairman of the Council).
Marquess of Aberdeen and Temair, P.C., K.T., G.C.M.G., G.C.V.O.
Lord Askwith, K.C.B., K.C., D.C.L.
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Viscount Chelmsford, G.M.S.I., G.C.M.G., G.M.I.E., G.B.E.
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Edward Dent.
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W. L. Griffith.
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James McNeill (High Commissioner for the Irish Free State).

Sir Charles T. Metcalfe, Bt.

Sir Francis J. Newton, K.C.M.G., C.V.O. (High Commissioner for S. Rhodesia).

Hon. Sir James Parr, K.C.M.G. (High Commissioner for New Zealand).

Hon. Frederick A. Pauline (Agent-General for British Columbia).

Sir Robert W. Perks, Bt.

Charles Ponsonby.

John Lloyd Price (Agent-General for S. Australia).

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M. L. Shepherd, I.S.O.

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Lt.-Col. Hon. R. E. Snowden (Agent-General for Tasmania).

Major H. Blake Taylor, C.B.E.

Carmichael Thomas.

Sir Archibald Weigall, K.C.M.G.

Lt.-Col. Sir Arnold T. Wilson, K.C.I.E., C.S.I., C.M.G., D.S.O.

W. Perry, B.A., Secretary.

PROCEEDINGS OF THE SOCIETY.

CANTOR LECTURES.

PHOTO-ELASTIC MEASUREMENTS OF STRESS DISTRIBUTION.

By PROFESSOR E. G. COKER, M.A., D.Sc., F.R.S., M.Inst.C.E.,
of University College, London.

LECTURE II.—*Delivered February 21st, 1927.*

In the previous lecture some account was given of the measurement of stress along the boundaries of plates in which notches are cut, and it was seen that the process is a very simple one of comparing colours, or, preferably, reducing the colour at the desired point to blackness by the device of interposing a tension member in a definite direction, and loading it until a black field is produced. In the interior of a plate, however, where there are usually two

stresses P and Q at right angles, we obtain

$$T_1 = P - Q$$

where T_1 is the stress in the tension member cut from the same plate as the model. We have, therefore to separate P from Q in this combination. It is possible to do this by purely optical measurements, but it is generally more convenient to make a further measurement of the sum of these stresses. This can be accomplished by a purely mechanical observation depending on an elastic property of the material.

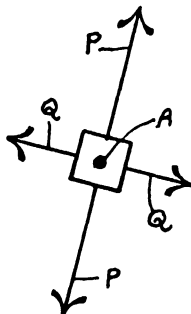


FIG. 12.—The measurement of the sum $P + Q$, of the principal stresses.

Consider what happens to an elemental square surrounding a point A , Fig. 12, of the elastic plate due to the effect of these principal stresses P and Q , which are taken as unequal here but of the same sign for purposes of illustration. The pull exerted by the stress P lengthens the element in the direction of the stress, and also causes it to shrink in thickness by an amount proportional to P . The Q pair has precisely the same effect, so that the total change of thickness is proportional to the algebraic sum $(P + Q)$ of the stresses at the point. This is true for any type of combination of principal stresses, whether tension or compression, as may be easily verified. If, therefore, we compare this with that found in the reference tension member cut from the same plate as our specimen, we can easily find that stress T_2 produces the same change in thickness, and, subject to small corrections which need not detain us here, we have therefore

$$T_2 = P + Q.$$

Now we have already seen from our optical measurements that

$$T_1 = P - Q$$

and hence $P = \frac{1}{2}(T_1 + T_2)$ and $Q = \frac{1}{2}(T_2 - T_1)$.

As we already know the directions of both P and Q from the isoclinic bands, the state of stress at any point can be completely determined in this manner without reference to any form of calculation.

Since the measurements of the sum $(P + Q)$ and the difference $(P - Q)$, of the principal stresses at a point are determined by reference to the same tension member, this avoids all necessity for knowing either the physical or optical constants of the material, as they are the same for both.

As will be evident, the accurate measurement of the change of thickness in a plate under load is a somewhat delicate operation, and in my Cantor Lectures of 1913 a form of apparatus was described for effecting this, and in principle it remains the same, but the details have been so improved that it is somewhat

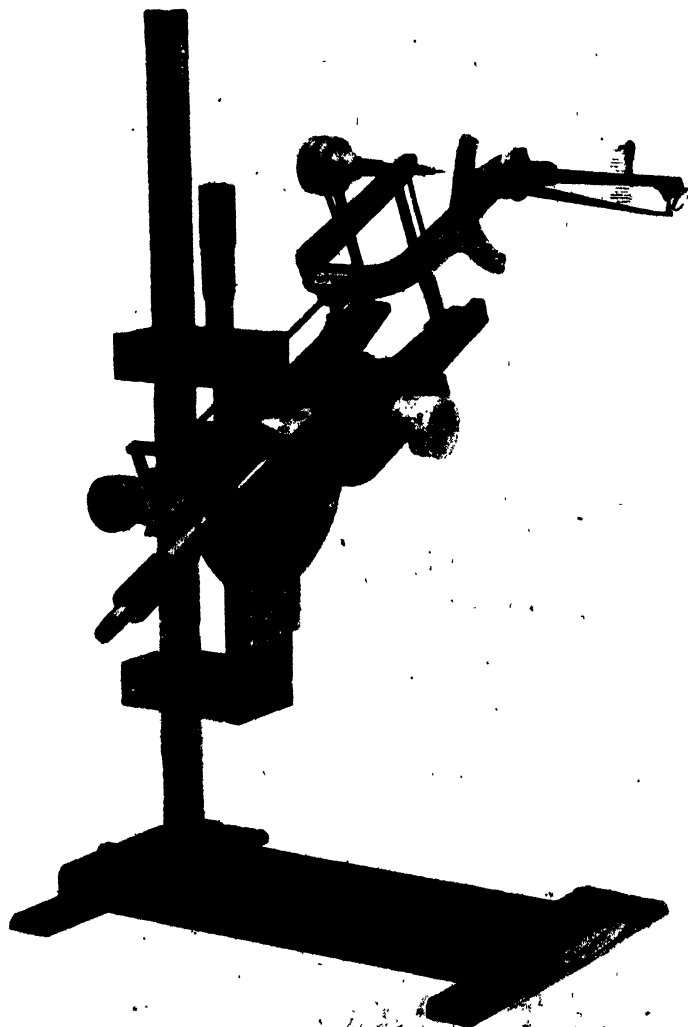


FIG. 13.—A lateral extensometer for photo-elastic experiments.

difficult to recognise it as the same instrument. Its essential features are the employment of two needles in line, one on each side of the plate and normal to it. These are pressed lightly against the surfaces so that no scratching or marking is possible, as this would destroy the truth of the measurement.

Any alteration in the thickness causes these needles to move in or out relatively to one another, and so move a multiplying gear which turns a small mirror upon which a light is thrown. The movement of the reflected spot of light is a measure of the sum ($P + Q$) of the stresses. A minor improvement, in the arrangement of springs used to hold the needles up to the work, is a division of labour; one spring is attached to one of the needles and another to the multiplying gear, and this gives a marked improvement in accuracy.

Another improvement is in the mounting. The lateral extensometer is hung from a three-point support carried on a somewhat complicated slide rest, which enables the instrument to be set to read at any desired point of the plate to an accuracy of one-thousandth of an inch, and there are slave micrometers which can be used for setting, so that no matter what the position may be, the main micrometers can start from a zero reading. This modified instrument is shown in Fig. 13, and since it has often to be used in somewhat awkward positions it is convenient to arrange it with only one main vertical support as shown.

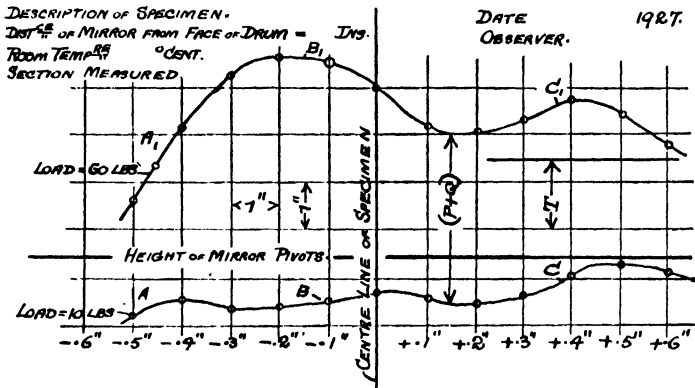
In many inclined positions of the extensometer the spot of light is thrown on the screen in an inclined position, and this makes measurement awkward. This can be avoided, however, by arranging all the multiplying gear to swivel round the common axis of the measuring needles to bring the travel of the spot of light into a vertical plane for every kind of measurement. For all these purposes it is necessary to provide a number of micrometer screws and graduated arcs, as will be observed in the photograph.

In general such an instrument is used by traversing along a line in the model taking measurements at, say, every twentieth of an inch. Hence, to cover a square inch of area it appears that 400 separate measurements will be required, but, in fact, we require 800, because the changes of thickness due to stress are so minute that they are often smaller than the variations of the natural thickness of the plate, and these latter have, therefore, to be measured also.

The labour of writing down such a large number of observations and subsequently reducing them to order was soon found to be far greater than observing them, and some means had to be devised to shorten the process. Ultimately all note-book work was abolished by the simple device of registering each observation on a vertical cylinder around which is wrapped a large sheet of squared paper, Fig. 14.

It is usually found convenient to make all vertical lines half-an-inch apart to correspond to points on any given line of the specimen some standard unit distance apart, say $1/20$ of an inch.

Starting from one end of this line the instrument is traversed along it, and as it comes to each point where measurements are to be taken the intersection of the reading wire is taken with the corresponding vertical line on the paper. The barrel is turned round as required for this purpose. The lower curve

FIG. 14.—Specimen record sheet of $P + Q$ measurements.

A, B, C drawn through these points represents the variation in natural thickness of the plate and usually also a small initial load. The total thickness would be given by the distance between this curve and another horizontal line several yards below this, but this latter line is not required, as it is only the change of thickness which is necessary for our measurements. If now load is applied and the instrument traversed along the same line, a new curve A_1, B_1, C_1 will be found, and the ordinates between the two will be a measure of $(P + Q)$, subject to some small corrections. It only remains to add a scale of stress T , which is found from the reference member in pure tension, and we then have a complete set of measured readings of $(P + Q)$ for this line. In addition every other item of useful information observed is added to this sheet, which can then be handed over to a computer for measuring up, or the observer himself does any arithmetic required.

Having described all the essential features of the photo-elastic process we will now go through the complete process of determining the stress distribution along a line of some body.

A convenient example is offered by the curved beam shown in Fig. 15, with

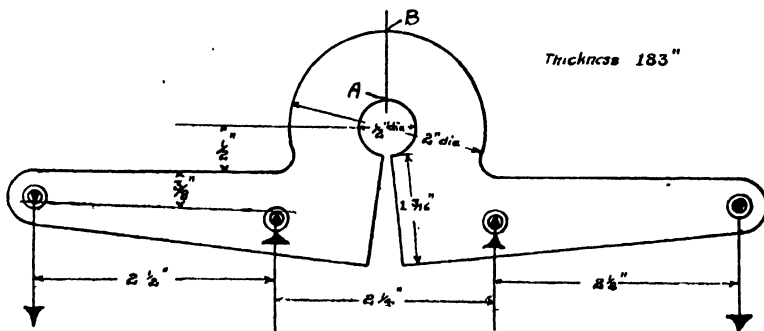


FIG. 15.—Curved beam loaded to produce a pure bending moment between the two inner supports.

an outer radius $R_0 = 1$ inch and an inner radius $R_1 = \frac{1}{2}$ inch. A simple way of loading it so as to give pure bending moment at the central section A B is to provide this model with arms containing holes bushed with steel rings for the insertion of knife-edges for the application of loads. The two inner knife-edges are supported to give vertical reactions, and the outer arms are loaded with equal dead weights. This arrangement of loads produces a pure bending moment on the central section of a known amount. When this beam is viewed under load in plane polarized light, the inclination of which is varied, isoclinic bands are found as shown in Fig. 16, and their radial spacing indicates that the stress at and near the central section is directed radially and circumferentially. Near the inner supports, however, these directions change rapidly, owing to the influence of the reactions and the altered shape of the beam.

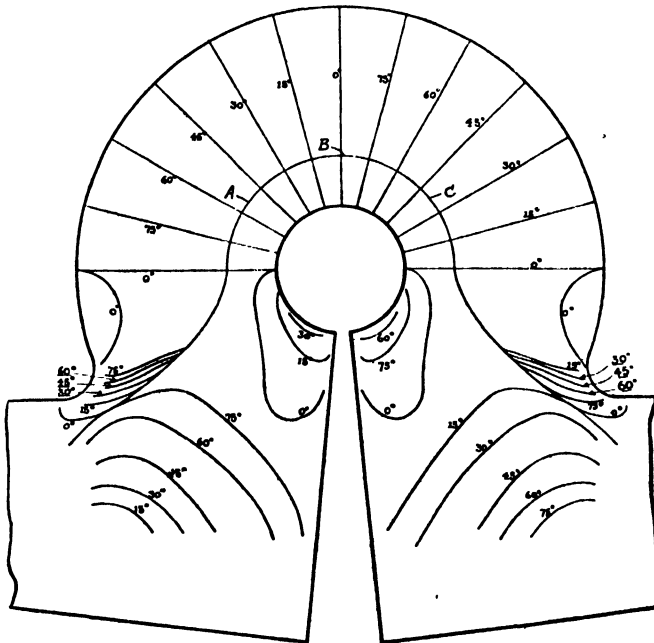


FIG. 16.—Isoclinics of a curved beam under pure bending moment.

One band, however, the curve A B C, remains invariable for every inclination of the plane polarized light, and its upper part is found to be a circle of radius $R_c = 0.425$ ins. At all points on this curve we must, therefore, have the condition $P - Q = 0$, in which P and Q are equal like stresses, and if both P and Q are zero this would be a true neutral axis, such as is found in a straight beam under similar loading. Subsequent measurements will show, however, that there is no place free from stress anywhere in this beam, and, therefore, this curve does not indicate a neutral axis. The drawing of the isoclinic

bands marks all the directions of stress in the beam, but a more convenient diagram is obtained by tracing curves upon it which are tangential to the direction of the P and Q stresses at every point. This is carried out in Fig. 17,

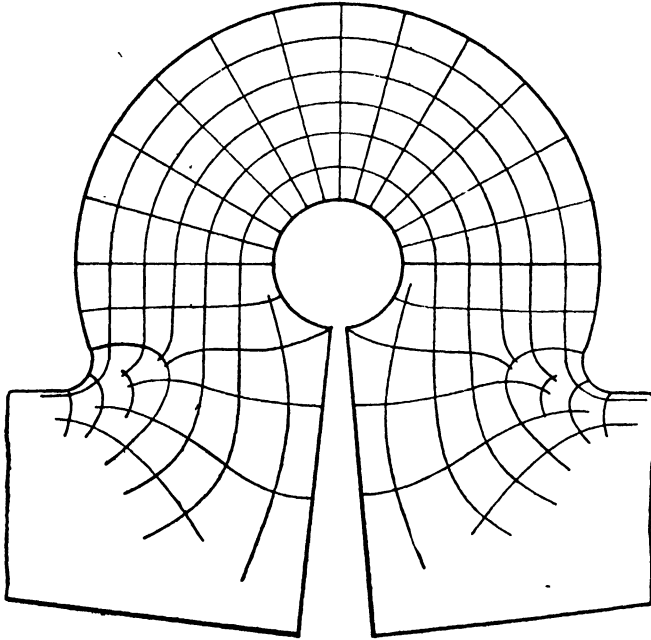


FIG. 17.—Lines of principal stress in a curved beam under pure bending moment.

but the isoclinic bands from which the curves are derived are omitted for the sake of clearness.

TABLE I.

EXPERIMENTAL VALUES.					CALCULATED VALUES.			
Distce.	P + Q	P—Q	P	Q	P + Q	P—Q	P	Q
0	1035	1035	1035	0	1005	1005	1005	0
.025	920	710	815	105	904	740	820	84
.125	600	142	371	229	598	165	381	217
.225	300	— 85	107	193	346	— 93	127	219
.325	142	—213	— 35	177	151	—225	— 37	188
.425	25	—298	—161	136	—139	—304	—159	145
.525	—170	—341	—255	85	—156	—354	—255	99
.625	—300	—383	—341	41	—282	—392	—336	54
.725	—400	—426	—413	13	—391	—413	—402	11
.750	—426	—426	—426	0	—417	—417	—417	0

We shall now proceed to measure the stress along the vertical section A B, and from Figs. 16 and 17 it is clear that the state of stress there is also obtained for all the radial sections on each side of it for a considerable angular distance.

It is convenient for this examination to use circularly polarized light, which is obtained by interposing a quarter wave plate in the beam after it has passed through the polarizing apparatus as already described.

Taking a convenient number of points on the section, the values of $(P + Q)$ are measured as already described. The results obtained are recorded in Table I and are also plotted in Fig. 18, as two curves C E D and C G D. The mean curve C F D gives the stress P across the section A B, and the difference between this latter curve and either of the other two shows the normal stress Q

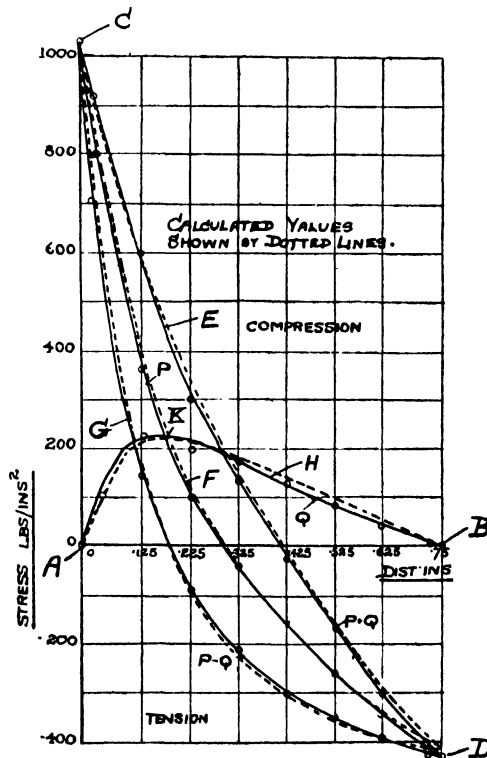


FIG. 18.—Stress distribution at the cross section of a curved beam.

on planes at right angles to this section. These latter observations are replotted on the base A B to give a more convenient distribution curve A H B.

We now see that the effect of pure bending on a curved beam is to produce a variable stress across a radial section, and in addition a variable normal stress, on planes perpendicular to this cross section; moreover, there is no point entirely free from one or other stress. The cross stress is zero at the ends of the section, but may be considerable in the interior of the beam. It is

often neglected in designing, although it may be of considerable intensity, especially in I beam sections, such as are used in the frames of punching and riveting machines, where the web is often comparatively thin. In most practical cases we cannot, in fact, neglect this radial stress as of small importance, nor can we, as is sometimes done, assume that the stresses in a curved beam are of the same type as those in a straight beam. They are clearly very different and of a more complicated kind.

In this example we have some means of checking the accuracy of the results. The total normal stress on the section must be zero, since it only tends to rotate the section, but does not tend to move it bodily in the normal direction. Adopting the usual conventions for labelling stresses, we have, in fact, this condition, expressed graphically, that the curve C F D is such that the area above the line A B is equal to the area below the line. With the reference squares of Fig. 18 of $\frac{1}{2}$ in. side, we find these to be 2.74 sq. ins. and 2.71 sq. ins. respectively as a proof of this.

We have, moreover, other tests of the accuracy of the measurements, since the stress distribution in this form of beam can be calculated in terms of the bending moment M and the inner and outer radii R_1 and R_0 . We will not go through this computation, but it is not very difficult to show, for a beam of thickness t , that at any radius r the stresses are given by

$$P = \frac{M}{tC} \left\{ (R_0^2 - R_1^2) + R_0^2 \log_{\epsilon} \frac{r}{R_0} - R_1^2 \log_{\epsilon} \frac{r}{R_1} - \frac{R_0^2 R_1^2}{r^2} \log_{\epsilon} \frac{R_0}{R_1} \right\}$$

$$Q = \frac{M}{tC} \left\{ (R_0^2 - R_1^2) \log_{\epsilon} \frac{r}{R_0} + \left(\frac{R_0^2}{r^2} - 1 \right) R_1^2 \log_{\epsilon} \frac{R_0}{R_1} \right\}$$

$$\text{where } C = \frac{1}{2} (R_0^2 - R_1^2)^2 - R_0^2 R_1^2 \left(\log_{\epsilon} \frac{R_0}{R_1} \right)^2$$

When these calculations are made, as in Table I, and are plotted, as shown by dotted lines in Fig. 18, it is seen that the agreement is a very close one, as indeed it should be if the experiments are carefully made.

Another interesting confirmation is obtained from the position where $P - Q$ is zero, and marked in Fig. 18 by the intersection of the P and Q curves at K , from which it appears that this point is distant .175 ins. from the inner contour, *i.e.*, at a radius of .425 ins.

From the above formulæ we have

$$P - Q = \frac{M}{tC} \left\{ R_0^2 - R_1^2 - \frac{2R_0^2 R_1^2}{r^2} \log_{\epsilon} \frac{R_0}{R_1} \right\} = 0.$$

and therefore

$$r = \sqrt{2 \cdot \frac{R_0^2 R_1^2}{R_0^2 - R_1^2} \log_{\epsilon} \frac{R_0}{R_1}} = 0.430 \text{ inches.}$$

so that our experimental error is only in the third decimal place and is another substantial proof of the accuracy of the observations. At this radius Q is a

maximum, as may be proved from the above formulæ, and is confirmed by experiment.

It has been convenient to consider this case in some detail, not only on account of its importance to engineers, but also as a confirmation of a theoretical result in stress distribution, which has been obtained independently by several investigators.* The substantial accuracy of the experimental measurements indicates that we may hope to obtain equally good results by photo-elastic means in problems which are at present quite insoluble by theoretical analysis. The great majority of engineering problems of stress distribution are, in fact, of this latter type. Many of them have only a superficial resemblance to simple cases solvable by elementary formulæ obtained with very definite limiting assumptions. This was apparent in some designs of crane hooks before the great influence of curvature on stress distribution was well known. Engineers have to be very careful not to carry their formulæ beyond their useful range. If these limits are passed and no accurate solution is available, it is very necessary to ascertain by experiment what is the possible maximum error in such calculations.

Among the innumerable problems which present themselves for solution, the links of chains afford most interesting cases of curved beams under stress. Approximate calculations of stress are given in most text-books, but a really accurate solution was unknown until my colleague, Prof. Filon, F.R.S., obtained one,† quite recently, for a circular link. All the more complicated cases of chains with studs, elliptical links with and without studs, have apparently proved incalculable so far, but approximate values of stress distribution have been obtained based on very simplified assumptions. On account of this lack of real knowledge of stress distribution, experiment is of great value here, and, as is well known, crane and anchor chains and the like generally pass stringent tests when manufactured, and also at intervals after use. Photo-elastic observations give a very valuable picture of the state of stress in chain links, as in the link shown under stress in Fig. 19, of which the centre line is a true ellipse with a major axis of 2.5 inches, a minor axis of 1.25 inches, and a mean width of $\frac{3}{8}$ inch, so that the contours themselves are not quite true ellipses.

The load in this case is applied by nitro-cellulose discs cut from the same plate and bushed to carry pins by aid of which a tension load is put on the model. The complicated character of the stress distribution is revealed at once by the isoclinic bands shown on the left hand of this Fig. 20, from which

* "Probleme der Spannungsverteilung in ebenen Systemen einfach gelöst mit Hilfe der Airyschen Funktion," by A. Timpe, Göttingen Dissertation, Leipzig, 1905.

"The Strength of Hooks and Similar Curved Beams," Engineering, September 5th, 1913.

"Curved Beams," by J. J. Guest, Proc.R.S., Vol. 95A.

Some Special Cases of two Dimensional Stress or Strain," by Prof. C. E. Inglis. Transactions of the Institution of Naval Architects, Spring Meeting, 1922.

† "The Stresses in a Circular Ring," by Prof. Filon, F.R.S., The Institution of Civil Engineers, 1924.



FIG. 19.—A loaded elliptical link viewed in circularly polarized light.

the directions of principal stress all over the link have been obtained as drawn on the right hand of the same figure. From this latter figure it will be seen at once that on nearly all sections drawn perpendicular to the central elliptical line there will be both normal stress p_n and tangential or shear stress p_s . Their distribution on a good many sections have been worked out experimentally by photo-elastic means, and some of these are shown in Fig. 21 when reduced to give results for a thickness of 0.1 inch and a load of 100 pounds. There are in addition normal cross stresses p_r , which have not so far been taken into account in theoretical calculations. The measurements also show that at the section A B the stress throughout is small, and is therefore a convenient position for a weld.

Another important case of a curved beam is found in the piston rings almost universally used in the piston of reciprocating engines. The stresses in such cases have not yet been examined photo-elastically in any great detail, but a good general idea of the state of stress in an ordinary piston ring of uniform width is obtainable from the photograph, Fig. 22, in which the width has been made very large in order to show the type of stress distribution obtained. It is seen and has been shown by measurement that the stress distribution at any radial cross section is of approximately the type indicated in the more simple case of a uniformly bent beam, but here the stress distribution varies in intensity from section to section, and also changes its character near the ends, where a somewhat intense contact pressure is indicated by a characteristic set of colour bands resembling the iridescent colours shown in a peacock's tail feather. This denotes that considerable contact pressures exist at the cut ends, and it can also be demonstrated that this latter may be lessened

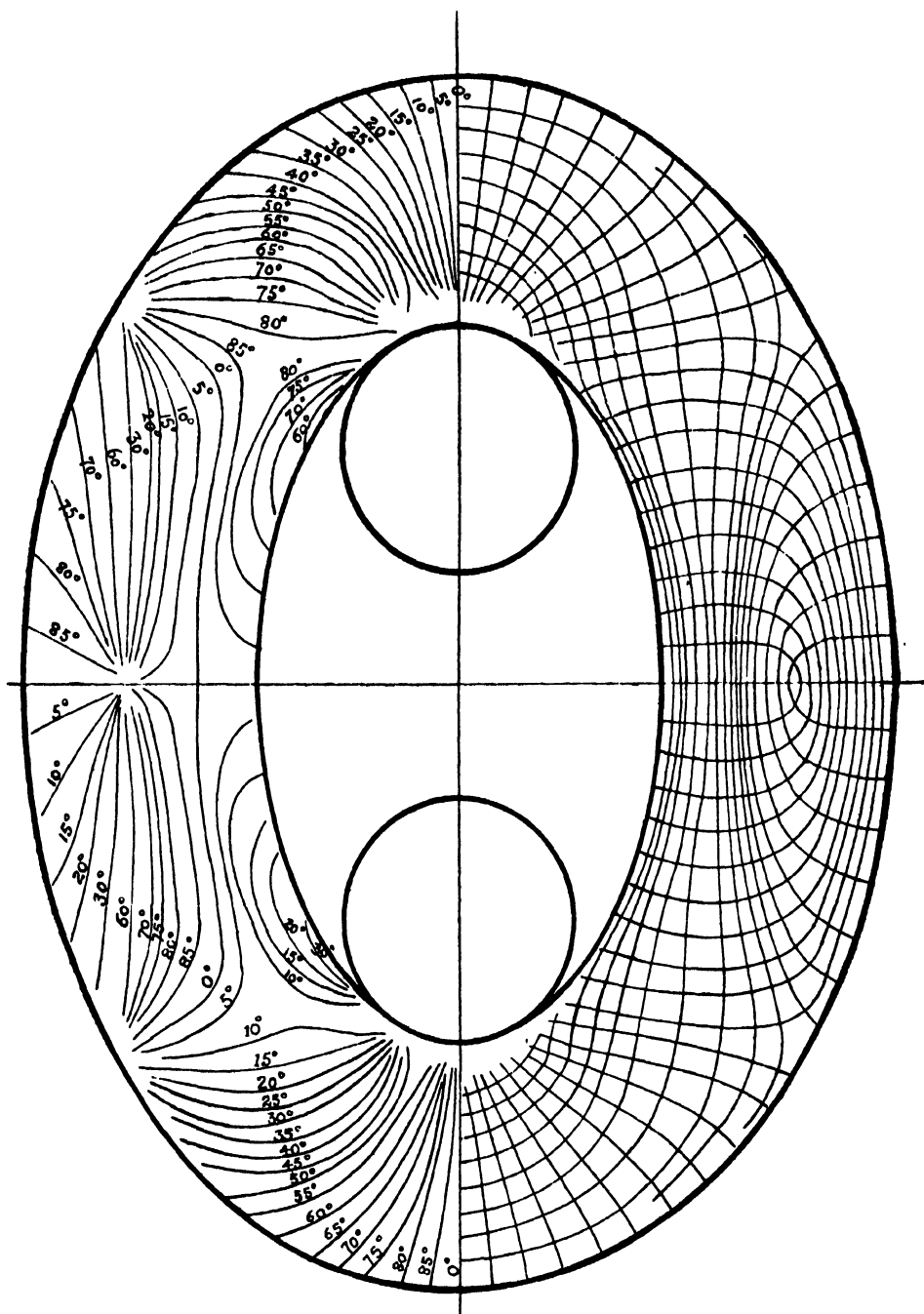


FIG. 20.—Isoclinics and lines of principal stress in an elliptical link.

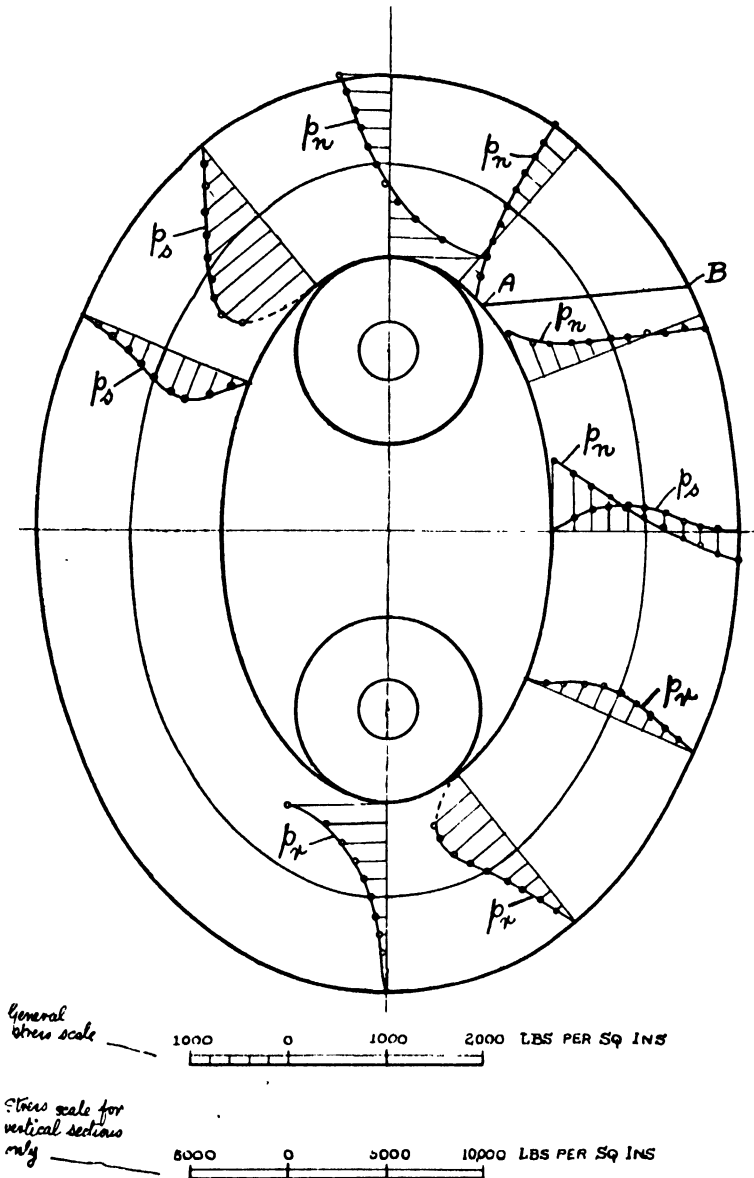


FIG. 21.—Stress distributions in an elliptical link.

very much by the use of a variable section ring which tends to prevent scoring of the cylinder by the end points.

The isoclinics and lines of principal stress for one such ring are shown in Fig. 23 taken from the paper cited above, which may be referred to for details of the stress distribution.

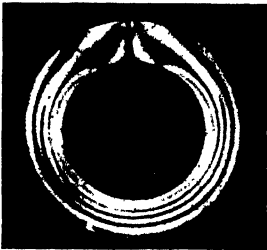


FIG. 22.—A very thick piston ring sprung into a cylinder.

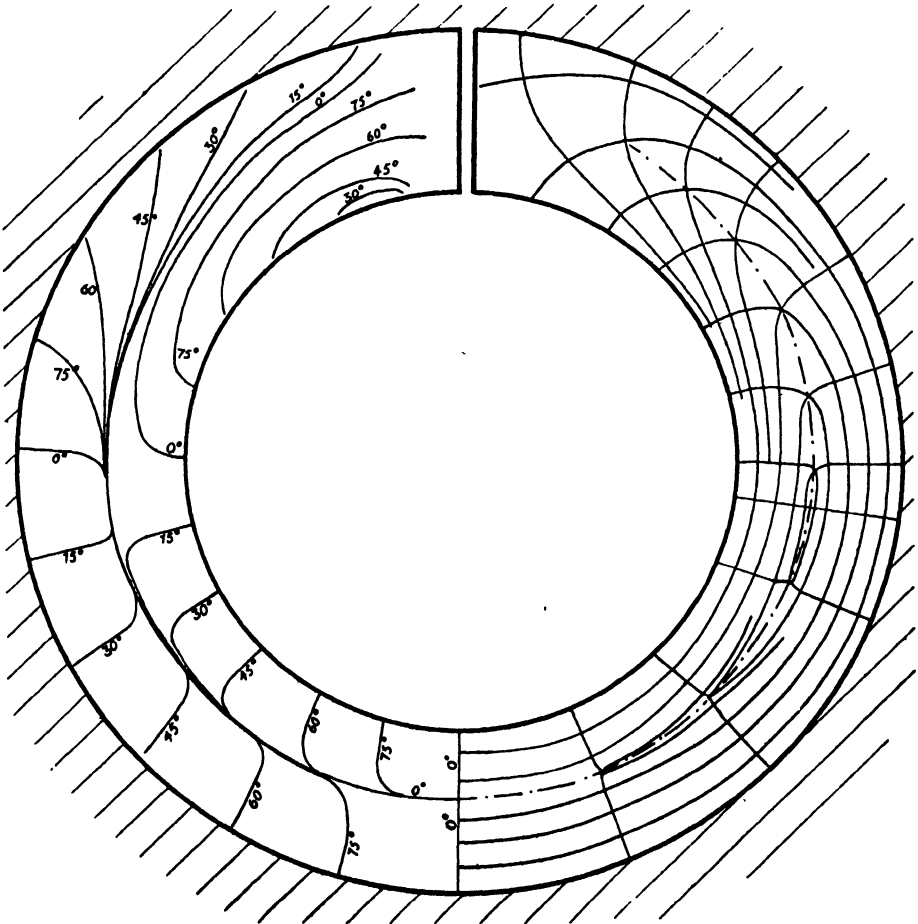


FIG. 23.—Isoclinics and lines of principal stress in a very thick piston ring.

CONTACT PRESSURES AND STRESSES.

The importance of an intimate knowledge of contact pressures and stresses to engineers is immediately obvious when we consider the numerous devices of so-called point, line and surface contact used in practice, like ball and roller bearings, gear wheels, machine tool sliding surfaces, and others too numerous to mention, which form essential parts of modern machinery. It is only possible here to describe a few of the experimental facts which can be derived from photo-elastic experiments. Commencing with an elementary form of line contact, such as is represented by the application of a single load P , normal to the edge of a plate, the picture of stress produced is a group of circles with centres on the line of load and all touching the point of contact. With a single concentrated normal load there is only one type of stress, a radial pressure in the plate away from the point of application and of intensity $\frac{2P}{\pi} \frac{\cos \theta}{r}$ where r, θ represent the co-ordinates of any point when the point of application is taken as the origin, and the direction of the force as the line of reference for measuring angles. The directions of the lines of stress and the stress intensities are indicated in Fig. 24.

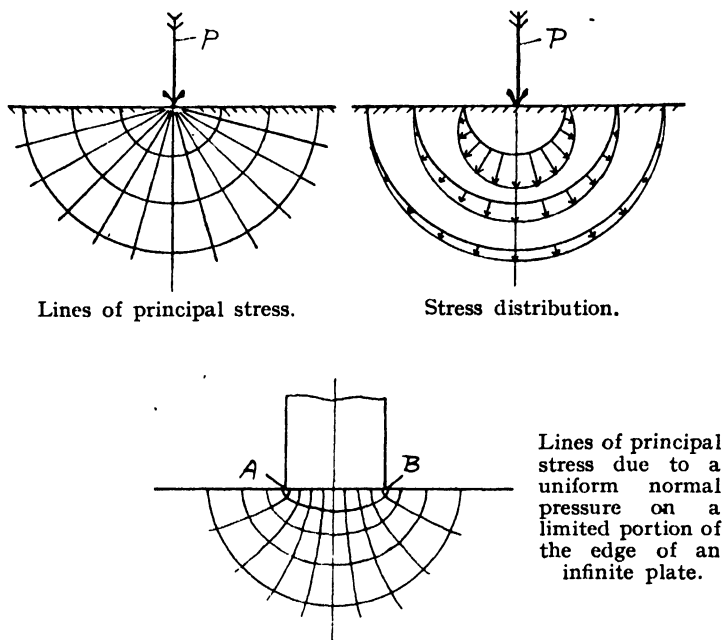


FIG. 24.—Stress distributions due to a normal concentrated load P and a uniformly distributed load on the edge of a plate.

Experiment verifies this formula, except for places very close to the point of application, where the theoretical formula does not hold, for the simple reason that line contact in the mathematical sense is an impossibility. In every practical case we have the load distributed over some area, however small. Moreover, it is practically impossible to distribute it uniformly, and hence we find a different and lower distribution near the point of application, as might be expected, for the stress at a radius r_0 in the above formula cannot approach infinity in any material. The nature of the actual distribution is more clearly shown if we attempt to load a part of the edge of a plate uniformly by pressing two plane surfaces together, as in Fig. 25, one of which is much wider than the

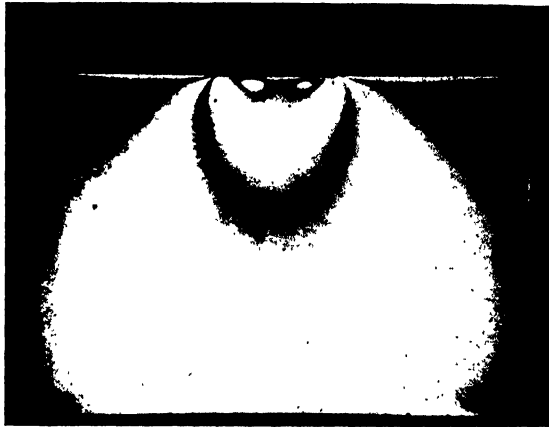


FIG. 25 —Stress effects produced in a block loaded centrally over one-quarter of its area.

other. We then get bands of colour for which $P - Q$ is a constant, terminating at the limits of the smaller plate, but we also observe that from these points there are other small loops of colour shooting out from these end points, and also a complicated colour band system directly under the loading plate, all indicating that the attempt to load a plate uniformly in this manner has not been successful. If this uniform loading could be accomplished in some way, and we draw two lines from the end points A, B, Fig. 26, of the smaller block to any point C in the plate with an included angle α , the stress can be repre-

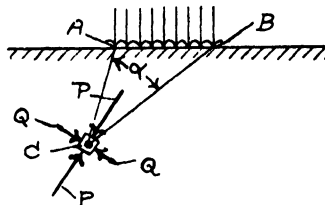


FIG. 26.—Stress distribution due to a uniformly distributed normal load on the edge of a plate.

sented by two normal stresses P and Q , of which P is directed along the bisector of the included angle α and Q is in the perpendicular direction, as indicated. The stress intensities are then

$$P = \frac{p}{\pi} (\alpha + \sin \alpha)$$

$$Q = \frac{p}{\pi} (\alpha - \sin \alpha)$$

as can be demonstrated mathematically.

We do, in fact, find this by experiment to be so, as long as we are not near the loading plane, but close up to the contact surface the stress distribution is different, owing to the circumstance that two plane surfaces when pressed normally together cannot apparently transmit pressure uniformly across the contact area unless they are similar and equal in area and are of the same material. Even then it requires great skill to obtain uniform pressure, as optical experiments show, and since nearly all the engineering interest in this type of problem is in the distribution and intensity of the contact pressures, it is important to know exactly what takes place. In all such cases we have great stress intensities at the ends of the pressing block, falling very rapidly towards the central line, accompanied by cross stress which is not, however, equal to the normal stress, as the above formulæ indicate for a theoretically perfect loading.

The directions of P , in a theoretically perfect case of loading, are along hyperbolic curves, as shown in the lower part of Fig. 24, having A and B as focal points and the line of contact as a principal axis, while the Q curves are, therefore, orthogonal ellipses with the same foci. Measurements of these directions show this almost up to the plane of separation, although the loading is necessarily non-uniform.

THICK CYLINDERS.

An important type of problem in many branches of engineering practice relates to the construction of cylinders subjected to very great internal pressures, such as hydraulic presses, cylinders for storing or compressing gases, like air and carbon dioxide, or to withstand explosions such as occur in rifles and big guns. In these latter we usually have two or more cylinders shrunk together so as to put a considerable compression stress on the innermost one, in order that this latter may be able to withstand the enormous pressures obtained with modern explosives, which may be higher than the tensile strength of the steel employed. It is not necessary here to go into the detailed calculations required for such problems, since these may be found in text-books on the theory of elasticity and gunnery manuals, but rather to show that photo-elasticity can be useful in some cases where calculations are difficult or even impossible.

Experimentally it is necessary to provide some arrangement for applying considerable pressures to the interior or exterior contours of short sections of cylinders, which will leave all the essential parts of the model free and clearly visible in the field of the polariscope. A conical wedge pressed into a ring affords an easy means of straining the interior contour by definite amounts and thereby to study the effect of shrinkage stresses, but if we require to apply a measurable fluid pressure, it is necessary to use some form of cup

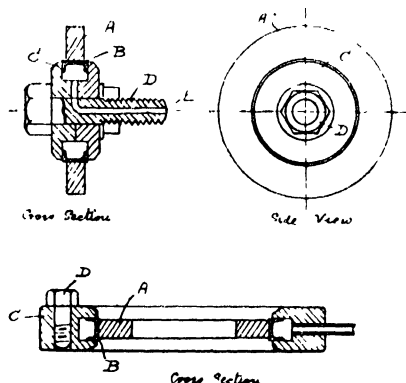


FIG. 27.—Apparatus for applying a measurable fluid pressure to the inner and outer contours of a ring.

leather to prevent the escape of the liquid. A device of this kind is shown in Fig. 27 for applying pressure to the internal surface of a ring A, which is carried on a flexible cup-leather B, fitting easily into a casing C, which latter is made in two halves and held together by a bolt D, while a pipe E serves to convey fluid under pressure to the inner face of the ring. The lower diagram shows a similar arrangement for applying stress to an external cylindrical boundary and is essentially of the same type. Some of the applied pressure is absorbed by the cup-leather, but as this latter can be made extremely thin, owing to the support it receives from the ring itself, the percentage allowance is small and is not difficult to determine experimentally. The cup leather is usually made rather wider than the ring under stress, and the depth of the side cheeks is kept as small as possible to ensure that the pressure is uniform over the contour. It is not difficult, in this way, to apply pressures of some thousands of pounds per square inch to sections of cylinders and find the stress distribution in them. In the simplest case, that of a cylinder with concentric contours, it is easy to show that the stress distribution agrees with that found by calculation.

Using well-known and easily proved formulæ, we have the radial $\widehat{rr}$ and the circumferential stress $\widehat{\theta\theta}$ at any radius r given by

$$\widehat{rr} = \frac{p_i r_i^2}{r_0^2 - r_i^2} \left(\frac{r_0^2}{r^2} - 1 \right) \quad \widehat{\theta\theta} = \frac{p_i r_i^2}{r_0^2 - r_i^2} \left(\frac{r_0^2}{r^2} + 1 \right)$$

where p_i is the internal pressure applied at the radius r_i and r_0 is the external

radius, so that

$$\widehat{rr} - \widehat{\theta\theta} = \frac{2p_i r_i^2 r_0^2}{r_0^3 - r_i^3} \cdot \frac{1}{r^2}$$

In the case of a ring with a bore $r_i = .76$ inches and $r_0 = 2.00$ inches, we find, under an effective pressure of 469 pounds per square inch that the values of $\widehat{rr} - \widehat{\theta\theta}$ calculated in this way

TABLE II.

Radius (inches)	...	...	...	.80	.90	1.00	1.10	1.50	1.90
$\widehat{rr} - \widehat{\theta\theta}$ (calculated)	pounds	per							
square inch	...	...	...	990	785	635	524	375	176
$(\widehat{rr} - \widehat{\theta\theta})$ (measured)	pounds	per							
square inch	...	...	...	1078	798	630	528	365	152

are as shown in Table II. The observed values are in sufficiently close agreement to prove that this form of experiment will afford an accurate idea of the distribution in more complicated cases.

One of these occasionally occurs when, owing to defective workmanship, the circular contours of the cross section are eccentric. This may happen in a cast pipe or cylinder owing to the core used in casting getting out of line, or in a seamless tube due to defective drawing. It is therefore necessary

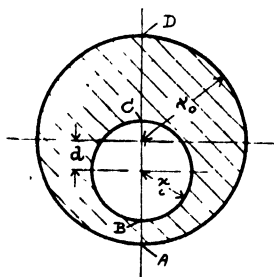


FIG. 28.—Diagram of an eccentric cylinder.

to be able to estimate the effect of this eccentricity. The experimental means described above enables this to be done. As an example we may take an eccentric ring of the form shown in Fig. 28, in which $r_i = .751$ inches and r_0 is .906 inches with a slight eccentricity d of .028 inches. We then find that under an internal pressure of 100 pounds per square inch, the stresses at four selected points A, B, C and D are as follows:—

TABLE III.

Point.				A	B	C	D
Measured circumferential stress $\widehat{\beta\beta}$ in pounds per square inch				560	642	466	351
Ditto calculated				560	663	464	336

These values agree remarkably well with those obtained from an exact theoretical expression* obtained at about the same time by my colleague, Prof. G. B. Jeffery, as Table III shows. Much more detailed confirmatory evidence has been published† for this type of cylinder.

In some cases, however, where cylinders are cast in blocks for motor-car engines, or are formed by boring out solid steel ingots, the boundary conditions become too difficult for calculations to be successful, and one such case is shown in the annexed diagram, Fig. 29, of a square section ingot, such as is

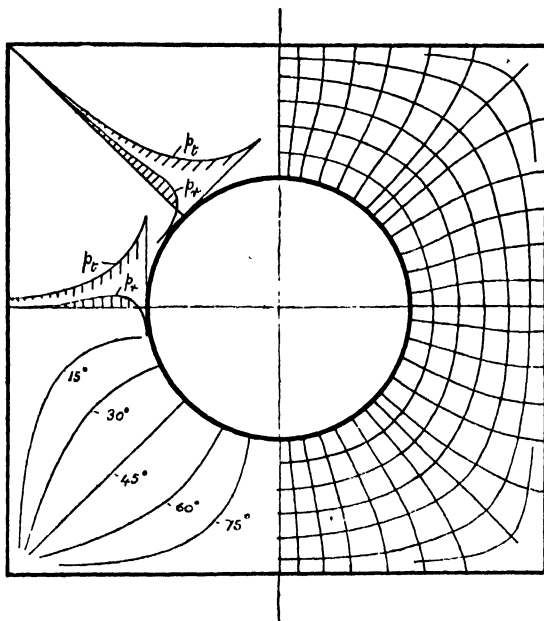


FIG. 29.—Isoclinics, lines of principal stress and stress distributions in a cylinder with an outer contour of square form.

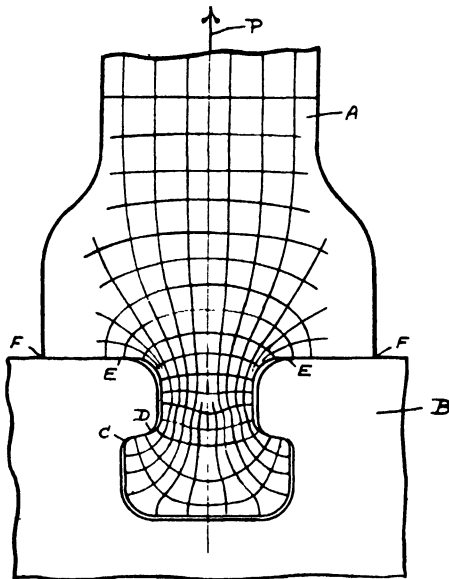
used for the cylinder for a CO₂ compressor of a refrigeration plant. Here the directions of stress and its distributions p_r and p_t along and across radial sections have been found by experiment in exactly the same manner as in previous cases.

* "Plane Stress and Plane Strain in Bi-polar co-ordinates," by G. B. Jeffery, Phil. Trans. Vol. 221, 1920.

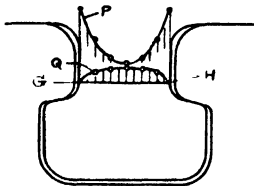
It has also been demonstrated† that it is quite possible to measure the stress distribution in built up cylinders such as occur in big guns.

Another interesting case of a thick cylinder of mechanical engineering interest occurs when a small toothed pinion is forced on to a shaft ; we then find that the proximity of the teeth to the internal contour causes the stress at this boundary to vary from point to point in a regular manner corresponding to the tooth spacing. When a key is inserted we get an extremely complicated type of stress in its neighbourhood, and in spite of this added discontinuity we still find some approach to this regularly variable stress at point of the inner contour well away from the key.

Other types of joint or fastening which have of late years become of great importance are various forms of dovetails, such as are used to fasten the blades of steam turbines to discs or drums, and in hydro-electrical and hydraulic engineering for securing members to rotating armatures and the like.



Lines of principal stress in a dove-tail joint.



Distribution of stress at the cross section GH.

FIG. 30.—The stress distribution in a dove-tail joint.

†† "Photo-Elasticity," by Prof. F. G. Coker, *Journal of The Franklin Institute*, March, 1925.

LOAD ON EACH PIN = 4.5 POUNDS.
ACTUAL THICKNESS OF PLATE = 0.185 INS.
EQUIVALENT STRESSES ARE GIVEN FOR A
PLATE 0.40 INCHES THICK.

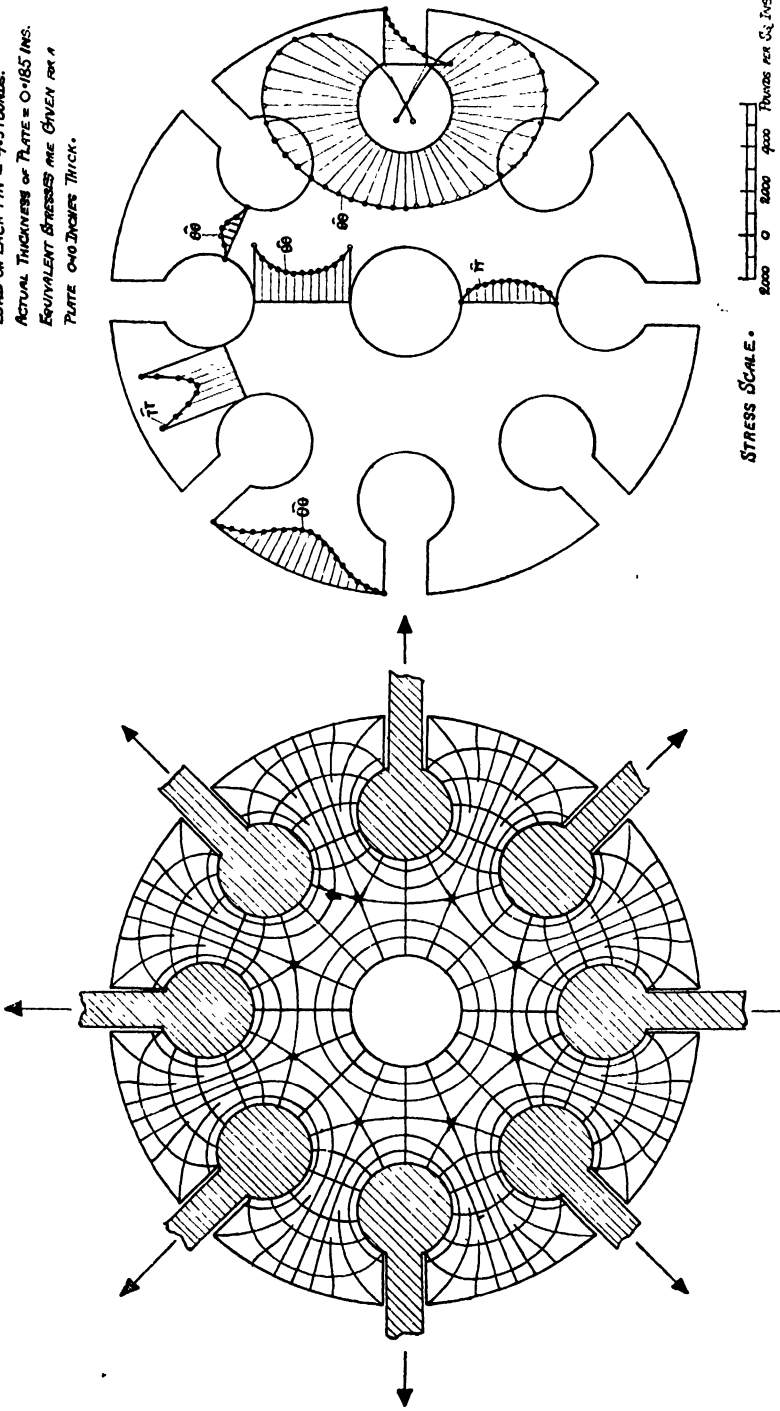


FIG. 31.—Lines of principal stress and distributions of stress in a circular plate loaded radially.

As an illustration we may take a member A, Fig. 30, secured in a block B by a dovetail, in which contact pressures are exerted over the inclined surfaces C D and E F. Under an axial load P the complicated character of the stress distribution is shown by the directions of the stresses marked on this figure. The stress in the dovetail varies from section to section and at one of these G H the stress distribution is shown to consist mainly of a normal stress P across the section, accompanied by a perpendicular stress Q accompanied by a slight amount of shear stress not shown in the figure, and due to the obliquity of the directions of principal stress with reference to this cross section, as is clear from the upper part of the figure.

In the vast majority of cases these dovetail joints are arranged in a circular pattern, and one of these (Fig. 4) has already been used as an illustration in a previous lecture. It may be useful to consider this further as a typical case, even although it has probably not been used in practice.

The equal radial loads are easy to provide here, from the colour scheme, since unless they are all exactly the same it is impossible to produce a regular colour pattern, but for measurement purposes it is necessary to know what these loads are, and in this example one of them is applied by a spring balance and all the others by screw attachments to the cylindrical studs which are in contact with the corresponding grooves in the plate. The lines of principal stress for this case are shown on the left-hand of Fig. 31, and it will be observed that at each of the isolated black dots, shown in an earlier photograph, Fig. 4, we now find several lines of stress using this as a cross-over point. This is a characteristic of all such points where $P - Q = 0$. Various stress distributions have been worked out, and are shown in the right-hand figure, the usual notation being employed to indicate the character of the stress, viz: $\hat{r}\hat{r}$ denotes a normal stress on planes perpendicular to a radius r and $\hat{\theta}\hat{\theta}$ is a normal stress on radial planes. We see here that at these nodal points $\hat{r}\hat{r}$ and $\hat{\theta}\hat{\theta}$ are nearly equal, as measured. Actually they must be equal.

NOTES ON BOOKS.

PAINT AND COLOUR MIXING. A Practical Handbook. By A. S. Jennings. Seventh Edition. London: The Trade Papers Publishing Co., Ltd., 329, High Holborn. 12s. 6d.

We have here 341 pages of text with numerous inset cards showing actual examples of commercial paints, so that the reader has available for observation and choice between one and two thousand small painted areas. A useful feature is the emphasis given to constancy of composition, and thorough mixing, without which no large work can appear satisfactory and uniform. Over twenty mixing devices are figured in the text, but a mixer which anyone can extemporise is that depicted on p. 28; a receptacle firmly set on a bench with a scraper or pestle to suit the vessel and an overhead ring to encircle the small upper end of the long stem of this agitator, or pestle.

Owing to the present state of the trade in paint and materials for paint, the market being crowded with proprietary articles sold under trade names, it would be unreasonable to expect full, detailed and exact chemical particulars ; but the author has maintained and extended the characteristics of the six previous editions which have followed in quick succession since 1902, and the volume in its present form will doubtless be highly acceptable to those for whom it is intended.

MODERN INDUSTRY. By E. L. Bogart, Professor of Economics in the University of Illinois, and C. E. Landon, Assistant Professor of Economics, Duke University. New York and London : Longmans, Green & Co. 16s. net.

This lavishly-illustrated volume of X + 594 pages is the most recent addition to the "Economic Series" of Messrs. Longmans, and its interest to the British reader is in no degree lessened by the fact that the work, as regards authorship and mechanical production, is wholly American. The authors take as their economic basis that old Athenian system which was extended and put into modern form by Adam Smith (1776). This system, after much study by Ricardo, Mill, and many others, culminates in the tenth edition of Seligman's *Principles of Economics*, published in 1925, and mentioned on p. 13 of the work under notice. Detailed studies, and practical exemplifications, are taken mainly from new aspects of industry which have come into being quite recently. Thus, in treating of "division of labour," the authors first touch lightly on Adam Smith's instance of the pin manufacture, but notable present-day examples are considered with a fulness of detail and pictorial illustration which give the work a special value. On p. 39 we find a whole-page illustration showing the entry office in a large store organised for sending goods by post. Here we see some hundreds of clerks sorting out items from the orders so that by a system of tickets and departments, the goods required by each customer may be quickly assembled, packed, and sent quite or almost by return of post. A more definitely technical or mechanical example of specialisation, division of labour and standardisation is gathered from the motor car industry, treated of in Chapter XXXV, "Assembling Industries : Automobiles," pp. 522-539. We are told that sixty per cent. of motor vehicles in the United States are used for business purposes, and that the "number of people travelling in automobiles now surpasses the number travelling in railway cars" (p. 538). Speed and system are exemplified by the eight pictures on pp. 534-535. The first picture shows the unloading of iron ore at a Ford works on a Monday morning at 8 o'clock ; the third shows a conveyor bringing the moulds past the pouring station, where the hot metal is cast into cylinder blocks, and the eighth picture shows cars as finished, and sometimes paid for, on the following Wednesday at noon ; a chief raw material (iron ore), received 52 hours previously, being thus converted into cash. Quick transformation, largely in parallel with the above, is the essence of the American system, and the details given of the inter-relation between wages and special skill, as also the organisation for making production march in like steps through the various departments so as to avoid slack currents or space-wasting accumulations (pp. 457 and 528), contain lessons which should be read and re-perused by every controller of an industrial concern in Great Britain.

The value of this work to the British reader does not only depend on its sound political economy with wide and detailed views of present-day technics, but also on the guidance it gives in realising how and why social and industrial conditions differ on the two sides of the Atlantic. The United States, as a nation, seems to have fully assimilated the lessons in economy conveyed by Mr. Carnegie's section on "The Cost of Government," which covers from pp. 318 to 326 in the 1888

edition of his *Triumphant Democracy*; while we, on the other hand, are in that first rush or flood of a democracy in which there seems to be but scant care or thought as to expense. In the *Evening Standard* of May 18th, 1927, Dean Inge, under the heading "A Century of Progress," discusses the democracy of our time: "wasteful democracy," he calls it. He says: "... it is becoming plain that democracy has done its work, that it is a most wasteful and unstable form of government, and that, in short, it is a luxury which we can no longer afford." The Dean of St. Paul's cannot be speaking of democracy in the broad sense, as American democracy operates economically, as also does the absolute democracy of Switzerland under the referendum and initiative. He evidently has in mind the actual British democracy of our time, to which a partial parallel is offered by Athens under Pericles from 461 to 437 B.C., during which time the Parthenon was commenced and completed. Election to magistracies became a matter of lot in certain cases, and the paid dicasteries were allowed to exercise high and various functions, although sometimes the dicasts appear to have been untrained persons, to whom a benefit of the nature of a dole was given.

In Great Britain, at the present time, we have frequent complaints in the newspapers with respect to an increasingly numerous class of expensive inspectors, superintendents and advisors; these being often paid by taxing industry at its roots rather than in its fruits or ultimate results; a system of taxation which for at least two thousand years has been regarded as unsound and analogous to taxing raw material. See Emerton's *Questions and Exercises in Political Economy*, Oxford, 1879, p. 92, and the references there given: also cf. pp. 108—110 of Emerton. The work under review very notably reflects economic views like those of Austin, and the teachings of the Oxford School in the seventies; thus on p. 14 we read of personal need as the driving force, and on pp. 574-580, we find a cogent plea for the utmost freedom to the industrialist as an individual.

As a thorough, lucid, and fully-illustrated treatise on great questions of the day the work under notice deserves a place in every public or private library, also in every industrial establishment.

PORTUGUESE EAST AFRICA.

H.M. Consul-General at Lourenço Marques prefaces his recent Report on the Commercial, Economic and Financial Condition of Portuguese East Africa by the following general remarks concerning the Colony:—

Portuguese East Africa, or Moçambique (Mozambique, in English), to give it its correct name, is the second largest of the Portuguese colonies. The coast line of 1,400 miles is washed by the Indian Ocean between 10° 40' and 26° 52' south latitude; inland the country is bordered entirely by British territory, being bounded by Natal and Swaziland on the south, by the Transvaal, Southern and Northern Rhodesia and Nyasaland on the west, and by Tanganyika on the north.

The Portuguese government exercises its authority directly through a Governor-General, with Governors acting under him in the districts of Lourenço Marques, Inhambane, Quelimane, Tete and Mozambique, and in a small territory south of the Rovuma River, which was assigned to Portugal by the Treaty of Versailles: the districts of Sofala and Manica are administered by the Companhia de Mozambique, whose 50-year charter dates from 1891, and the Companhia do Niassa holds a charter which expires in March, 1928, in respect of the territory lying to the east of Lake Nyasa and to the north of the River Lurio.

The legislative and executive powers of the colony are exercised at present by the Governor-General, who is under the immediate direction of the Minister for the

Colonies. The Governor-General is assisted by a Legislative Council of 17 members, 10 of them being the heads of local government departments. This form of administration, which replaced that existing under the direction of High Commissioners, has resulted in a lesser measure of self-government since its institution in 1926, and gives more direct power to the Colonial Minister who, in the present Lisbon administration, has an extensive personal knowledge of the province.

As is natural, the geographical situation of the colony has involved for many decades close commercial relations with the Transvaal, and from 1904 to 1923 an agreement, known as the Mozambique Convention, regulated these relations, dealing particularly with customs and railway matters and with the emigration of native labour to the Transvaal gold mines. It was denounced by the Union Government and has not yet been renewed, although the desire of both parties for an understanding capable of increasing the welfare and prosperity of each argues favourably for a successful termination to the negotiations which are to take place shortly at Cape Town. Agreements also exist for the free transit across Portuguese territory of imports to and exports from Rhodesia and Nyasaland, and for the control of the movement of native labour between the first named and Mozambique.

Though undoubtedly extremely rich, the development of the province is very backward, except on the seaboard and along the railway lines serving the British hinterlands of the Transvaal (Lourenço Marques and South African Railways), Southern Rhodesia (Beira, Mashonaland and Rhodesian Railway) and Nyasaland (Trans-Zambezia, Central Africa and Shire Highland Railways). Foreign, especially British, capital will probably become available for the development of the mineral and agricultural wealth of the interior when the stability of a sound colonial administration and the settlement of outstanding financial difficulties warrant this action.

INDUSTRIAL PROGRESS OF JAPAN.

According to a report by H.M. Consul at Osaka, Japan has made very notable industrial progress during the past fifty years. Cottage industries have been transformed and developed into modern factory organisations and various industries not native to the country have been introduced from Europe and America to meet the needs of a new age. New discoveries and methods have been imported from abroad, occasionally even evolved in the country, and put into effect to an exceptional extent.

Various obstacles have stood in the way of Japan's progress. Paucity of raw materials, the low standard of labour efficiency and technical skill, lack of capital, competition from other more advanced countries, restricted markets, and a number of disadvantages have had to be encountered, though by dint of the efforts of industrialists and with the help of education a fair degree of progress has been attained. That this progress owes much to the stimulus of the world war cannot be gainsaid, but without the factors mentioned and a certain energy and determination to succeed such attainment would have been impossible.

At the same time the percentage of imports of manufactured goods has been steadily decreasing, while that of raw materials has exhibited a great increase. On the other hand, the percentage of exports of raw materials has decreased, while that of exports of wholly manufactured goods has increased to a marked extent.

Of Japan's industries at the present time the textile industry is by far the most important, the chief branches of the industry being silk and cotton. The woollen industry, however, is also expanding very rapidly.

PROPOSED RESUSCITATION OF THE QUININE INDUSTRY OF PERU.

The cinchona tree is a native of Peru, and at one time flourished in all the Amazonian regions, but spoliation and wanton destruction without any attempt at replacement have reduced the existence of this shrub to almost negligible proportions.

According to a report by H.M. Consul at Callao, no attempt has ever been made to cultivate the plant in Peru, and the bark is now only gathered in scattered quantities in the Province of Tumbes, and Sullana, in the extreme north of Peru, adjoining the Ecuadorian frontier, and to a very small extent in the Province of La Convencion, Cuzco, in Southern Peru. In 1925 the export of Peruvian bark amounted to 46 tons, valued at £p.4,260, which went to Germany and France. On the other hand, Peru is obliged every year to import large quantities of the drug, in manufactured form, to combat the endemic plague of malaria from which half the population suffers. In the meantime Java has obtained control of the quinine producing trade, and exercises a virtual monopoly of the business. This situation has begun to alarm public health authorities throughout the world who realize the importance of a free market in this drug in the interests of malaria control, and at the Seventh Pan-American Sanitary Conference held in Washington in September, 1926, a resolution was passed recommending the resuscitation of the quinine industry in Ecuador and Peru. The recommendation has awakened a certain amount of interest in Peru, but it is recognised that if the scientific cultivation of the cinchona tree is to be attempted in that country, the enterprise must be assured of the material support of the Government, on account of the capital investment involved and the time the tree takes to reach maturity.

GENERAL NOTE.

BUILDING RESEARCH: FIRE RESISTANT CONSTRUCTION.—A special Report (No. 8) * dealing with the resistance of building materials to fire has been just published by the Department of Scientific and Industrial Research. Part I contains a brief outline of the effect of high temperatures upon materials in general, metals, timber, natural stones, bricks, etc.; while Part II is devoted to the fire-resistance of concrete.

The deterioration produced in concrete by fire is shown to be due to two main causes, one being the thermal expansion of the aggregate and the other the presence of free lime, which is dehydrated at the temperature attained in a building conflagration and slakes with expansion on subsequent exposure to moisture, causing complete failure of the structure.

The tests reported show that a good deal of the free lime in Portland cement concrete may be absorbed by the addition of pozzolanas, the resultant concrete showing, in some cases, a considerable degree of stability when exposed to the high temperatures; the value of various pozzolanas for the purpose is discussed.

Research on the lines of the work described in the Report is still proceeding. The special mixtures of Portland cement and pozzolanas have been kept under observation for over two years, both in the normal condition and after exposure to fire, and seem perfectly reliable. A further report will be published after five years' experience has been obtained.

* Obtainable, price 1s. 6d. net, postage extra, from H.M. Stationery Office, Adastral House, Kingsway, W.C.2., or through any bookseller.

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PROCEEDINGS OF THE SOCIETY.

CANTOR LECTURES.

PHOTO-ELASTIC MEASUREMENTS OF STRESS DISTRIBUTION.

By PROFESSOR E. G. COKER, M.A. D.Sc., F.R.S., M.INST.C.E.,
of UNIVERSITY COLLEGE, LONDON.

LECTURE III.—*Delivered February 28th, 1927.*

THE TESTING OF MATERIALS.

A knowledge of the properties of materials as regards their resistance to stress is a prime necessity for engineers, and ever since the use of metals in construction became general the subject has been studied with great and increasing vigour.

The so-called simple mechanical tests of materials in tension, compression and shear still form the staple of the laboratory tests on which engineers are accustomed to rely, in which may be included their variations due to bending of beams and the twisting of shafts, but in modern times, owing to the increase of scientific knowledge in all directions, many new methods have come into use, such as, for example, the use of the microscope for the examination of the crystalline structure of metals, especially when deformed by stress, and the examination of molecular and atomic structure by X rays.

Moreover, the discovery of new steels and other alloys, the general speeding up of machinery, and the ever increasing demands on engineers to supply modern needs, especially of transport by land, sea and air have brought in their train many new problems which have needed investigation, and have, in fact, been the impelling cause of much new and original work in this field. We have now a multiplicity of new and interesting ways of examining materials in order to elucidate their properties, some of which, although of great use, such as indentation tests for hardness, are still more or less empirical.

The true nature of even the so-called simplest methods for testing the mechanical properties of materials is well worth study, and it is proposed to examine some of the more elementary cases here by the aid of photo-elastic means, in order to elucidate their essential properties as far as is possible by this means.

The tensional properties of a material are a natural starting point, although the difficulty of applying the necessary load caused the earlier engineers to rely a good deal on bending tests of materials for information on both tension and compression. We have already seen in the case of a simple nut and bolt how very complicated the stress conditions are, due to the end connections, and we have to again look into this question and to examine the condition of the ends of a tension member when it is subjected to test, since, if there are disturbing complications anywhere, they must be sought for here.

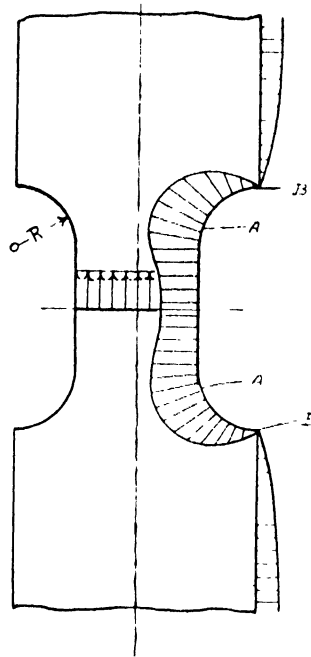


FIG. 32.—Stress distribution in a short tension member with enlarged ends.

Let us take for example a model of a plate tension member with a parallel central section connected to widened ends in the usual manner by circular arcs, and examine it under load in the polariscope. For the greater part of the central length the colour indications are quite uniform, due to a pure tensional stress, but near the ends the colour variations show that a more complex state of stress exists there, and also that the curved fillets are the cause of a local increase of stress at a point A, Fig. 32, just beyond the join to the straight sides and depending mainly on the radius R of the fillet and to some

extent on the increase in width of the ends. As this radius decreases the stress at A naturally becomes greater, and may easily be many times the stress at the central section, so that it is quite possible for a comparatively small load to cause a stress at this place which will cause plastic yielding to commence here, or, if the material is very brittle, a crack may be formed which, once started, will spread across the test bar and cause fracture.

If the state of stress is measured over the central part of the specimen, it is found that the effect of enlarged ends of this type is to cause the stress to increase along the sides until the maximum points A are reached and afterwards to diminish until at the points B the stress is zero. At the centre of this cross section joining the points B, the stress is a maximum for the section, and tends to remain a maximum at all higher sections until the effect of the discontinuity

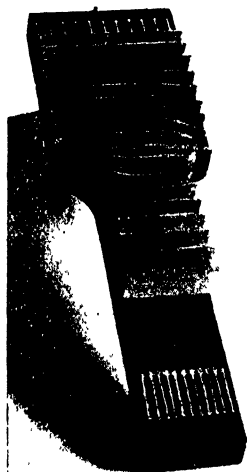


FIG. 33.—Model of the stress distribution at one end of a British standard tension test bar.

disappears. In order to make this point clear, a model has been constructed, Fig. 33, of a British Standard Tension Test Bar, in which the uniform intensity of stress at the central section and an enlarged end is represented by the lengths of the arrows shown. The plates standing up from the test bar and adjacent to these arrows are of the same height, and also represent the intensity of the normal stress across the section on which they stand. All the other sections are similarly treated to show the stress at these places, the whole model forming a graphical representation of the state of the stress caused by simple pull applied at the ends.

It is easy to understand that if a material is to be subjected to a pure tension test, the length under test must not come under the influence of the ends. This point is often disregarded, especially in short specimens, and the effect of this

neglect is important. So long as complex stress exists in the specimen the directions of principal stress are somewhat inclined to the axis of the bar and the limits of pure tension can therefore be found by determining the zero

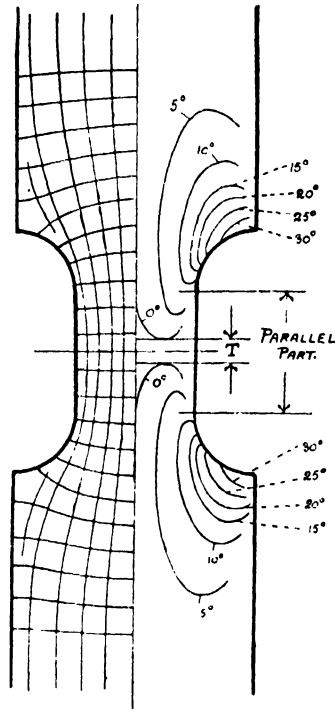


FIG. 34.—Tension member with enlarged ends showing the length "T" in pure tension.

isoclinics. In Fig. 34, for example, it is apparent that the length under pure tension is included between the central pair, and if, as sometimes happens, the test bar is specified to have a greater test length than this, some part of the specimen examined for pure tension will be under complex stress. It is, as can be seen from this diagram, quite possible, if these central isoclinics touch, to have a specimen with a short parallel central length so designed that no pull can possibly give pure tension anywhere except the central cross section. Specimens of circular cross section are still more defective in this respect than flat plate specimens, since the cross sections are proportional to the square of the linear dimensions, and the zero isoclinics are, therefore, a longer distance from the shoulders.

A good many detailed measurements illustrating this and other points have already been published* to which the reader may be referred for further information.

* "Photo-elastic Measurements of the stress distribution in tension members used in the testing of Materials," by Prof. E. G. Coker, F.R.S., M.Inst.C.E., Minutes of Proceedings of The Institution of Civil Engineers. Vol. ccviii, 1918-19, Part II.

One point of considerable interest in tests to destruction of ductile tension members is that, although it is evident that plastic failure must commence near the shoulders of a test piece, yet they rarely break there. This, however, is easily understood when it is realised that once a plastic condition commences it tends to spread into the central part and finally into the enlarged ends, so that a more or less uniform plastic state is developed over a large area and the chances of finding a weak place at some other point are very much increased, and the probability of final rupture commencing at the starting points of failure is much diminished.

THE DISTRIBUTION OF STRESS IN SHEAR SPECIMENS.

Another so-called simple test of the properties of engineering materials arises when a bar of rectangular or circular cross-section is subjected to shear.

This case has been examined by one of my former research pupils, Prof. T. Fukuda, using a specimen of the form shown in Fig. 35, in which a transparent beam C of rectangular cross section is supported by blocks D in a rigid frame E and is subjected to load by a block F loaded as uniformly as possible on its free upper face. In some cases the beam is provided with semi-circular notches to ensure fracture along the sections A B.

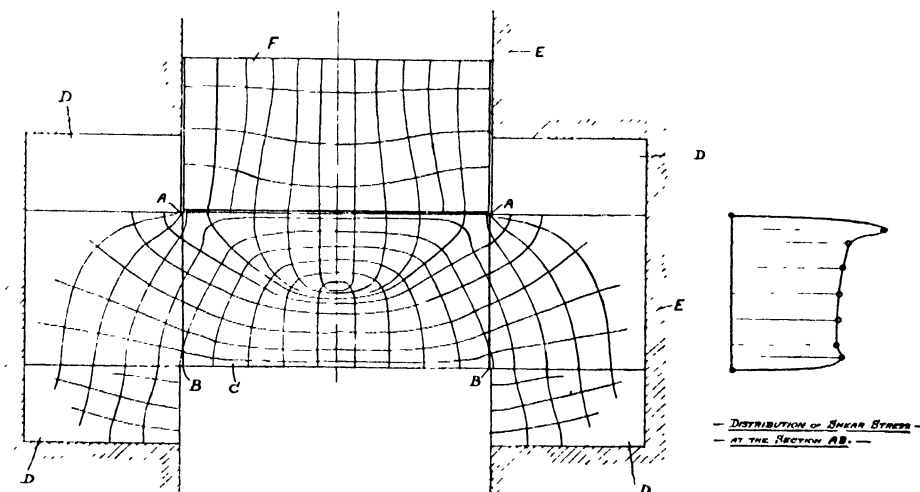


FIG. 35.—Lines of principal stress in a shear test specimen.

Taking the more simple case of a plain rectangular beam, it is found that the directions of the lines of principal stress are as shown in Fig. 35, from which it is at once clear that at the sections immediately under the ends of the block F the stress is not really a pure shear, since the directions are not at 45° to the planes under consideration, due to the practical difficulty of so fixing the ends that bending cannot take place.

Observations at these sections (Fig. 35) show that the principal stresses P and Q vary from point to point, with maxima intensities near the ends of the section of different magnitudes. Summing up the shear intensities at the cross section from the experimental results we find that the whole of the applied shear load is accounted for on the section. This example, therefore, while not really a case of simple shear, probably resembles the state of stress in ordinary shear tests. It illustrates the difficulty of obtaining the state of stress required in the material. More accurate measurements of shear stress have, in fact, been already described in my pre-war Cantor Lectures.

THE CEMENT BRIQUETTE.

A still more interesting case of a tension test arises in the testing of cement, in which the form of the briquette is prescribed by arbitrary rules, which differ from one country to another, and preclude any possibility of cement being tested in pure tension, or of obtaining consistent values of the tensile properties of this material. This will at once be realised from the foregoing discussion on end effects in steel tension members, since the form of a briquette is that of

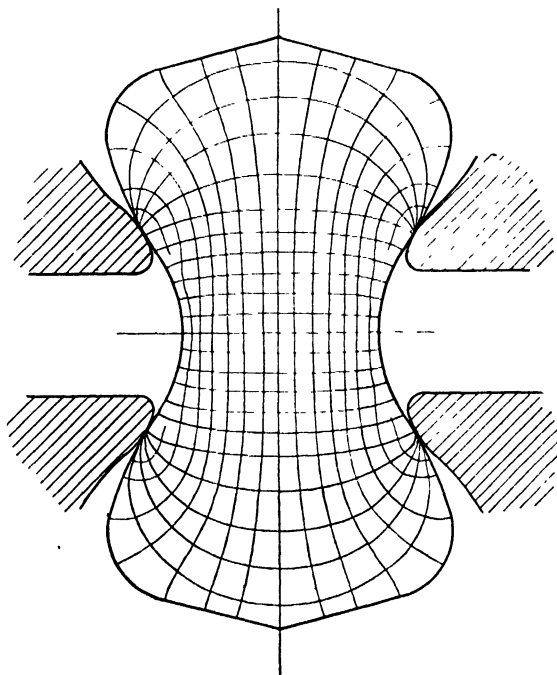


FIG. 36.—Lines of principal stress in a British Standard Cement Briquette.

two enlarged unsymmetrical ends united at a common cross section. The effect of the grips is to produce a very intense contact pressure in the small areas of contact at the central longitudinal section, and the lines of pressure of arched form spring across the intervening space as shown in Fig. 36 and are

met by orthogonally intersecting lines of which the central ones thread their way through the waist of the briquette. We will not stop here to discuss the whole of the stress system developed, which has been worked out in the Engineering Laboratories at University College, London, but content ourselves with conditions which obtain at the central section A B, Fig. 37.

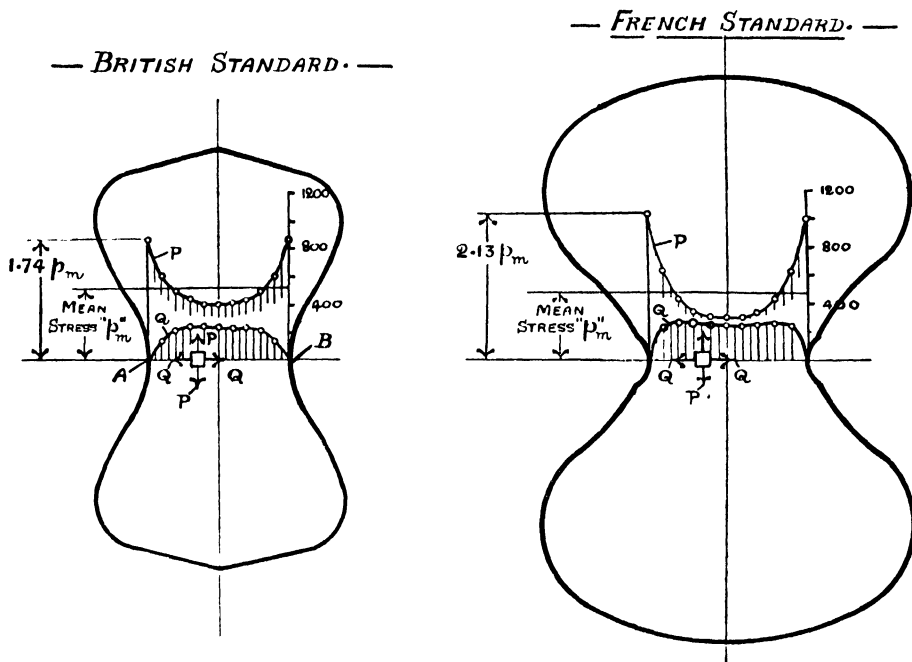


FIG. 37.—The distributions of stress at the central cross sections of standard British and French Cement Briquettes.

As will readily be observed the distinctive feature of the distribution in this case is an extremely variable tension P across the section accompanied by a variable cross-section Q at right angles of considerable magnitude. In this British form, for example, with a load giving a mean average stress of 500 lbs. per square inch, the highest value of P at the outer contour is 870 lbs. per square inch, or 1.74 times the value of the mean stress, while it sinks to 405 lbs. per square inch at the centre, or slightly more than 80 per cent. of the mean average value. In addition to this stress there is a cross-stress Q which rises rapidly from a zero value at the contour to a value of about 235 lb. per square inch for the central six-tenths of the cross-section, so that the manner of loading and the form of the section calls into play a cross-section of 47 per cent. of the mean average stress due to the pull. It is therefore seen that a member of this form is certainly not in pure tension, and the colour bands which are observed on the model indicate this quite clearly.

These results are generally applicable to American and Canadian standards, since these forms are practically the same as the British Standard.

The standard French form of briquette, Fig. 37, shows much the same kind of distribution, but in a more pronounced form, owing to its different shape, and especially to the circular indentations at the waist. In an actual test, shown in this Figure, a mean average stress of 470 lb. per square inch develops a maximum tensional stress P of approximately 1,000 lb. per square inch, or 2.13 times the average stress, sinking to a minimum value at the centre of 300 lb. per square inch, that is 64 per cent. of the average value. In some other experiments the ratio of the maximum stress f to the average value was found to be 2.05, 2.06 and 2.14, so that it appears very likely that this ratio is in the neighbourhood of 2.10. The stress system described above is also accompanied by a cross-tensional stress, which rises to its highest value near the ends of the cross-section, and has a slightly less minimum value at the centre of about 260 lb. per square inch, or 55 per cent. of the average pull applied, and not a great deal less than the tensional pull across the section at this place. A highly complex system of stress is, therefore, present at the cross-section for which the specimen is designed to fracture, and if anything like the same stress system prevails in the actual briquette, we cannot hope to learn anything very definite of the purely tensile properties of cement under such a complicated system of stresses in it.

French engineers have long been alive to the fact that the distribution across the central section is far from uniform, and Durant Claye* has proposed an ingenious approximate solution based on some elementary principles, in which he obtained a curve of distribution with pronounced maximum values at the ends of the section.

These are the main features of the stress distribution at the waists of both British and French standard briquettes. There is a good deal of work still to be done before any practical proposals can be adopted to obtain international uniformity in testing cement, for it has yet to be shown that the stress distribution in a cement briquette recently moulded is similar to that in a transparent model.

It has been proved† that the stress in a cement briquette of some age is of exactly the same kind as experiments on transparent models show, and this is to be expected, since old cement has very perfect elastic properties. The fact that sound vibrations are transmitted very rapidly through cement partition walls and floors shows this, and in another direction it has shown‡ that such cement possesses very perfect thermo-elastic properties. This latter property is not, however, possessed, or only imperfectly so, by cement which has been recently moulded, so that so far as this evidence can be taken

* "Annales des Ponts et Chaussées." Tome 9, serie 7. June, 1895.

† "The Relation of Thermal Change to Tension and Compression Stress," by E. G. Coker and C. M. McKergow. Transactions, Royal Society of Canada, 1904.

into account it points to the conclusion that briquettes tested at the end of a week and a month, as is sometimes provided for in standard specifications, will not be under exactly the same type of stress as transparent models show. They are most probably in a semi-elastic condition in which, as all the evidence we possess indicates, the stress distribution is less variable than in the purely elastic state, so that any provisions found necessary from experiments on elastic bodies will more than cover the requirements sought. The older the briquette the more nearly the stress distribution approximates to that of the elastic condition of the transparent model. The chief bar, however, to uniformity appears to be in the varying shapes of the briquettes themselves, but it is not impossible to devise a simple means whereby this difficulty could be overcome without the necessity of a wholesale scrapping of existing machinery. Briefly the proposal is to examine how far the uniformity of testing can be obtained by maintaining in every case the existing forms of the ends, and lengthening the central part by the addition of a parallel part of the least possible length which will satisfy the condition that the stress in that part is a uniform tension. Thus, if the British standard briquette is taken, and a definite parallel length is introduced, as shown in Fig. 38, the part in pure tension T is at once defined by the zero isoclinics as indicated.

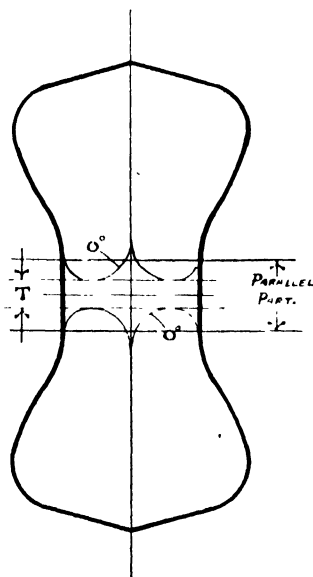


FIG. 38.—British Standard Cement Briquette with a central parallel part introduced.
The Briquette is in pure tension over a length "T."

Having established this length T by experiment, it is a simple matter to make the length in pure tension any quantity considered desirable, and this need only be a small fraction of an inch. Further experiment will then be necessary to find in the cement briquette the stress distribution at the waist

at various ages, and also to adjust the leading-in curves in such a fashion as to prevent stress concentration along them. It seems probable, if it can be established by measurements that there is uniformity of lateral contraction under load in each type of briquette lengthened in this way, that it will be generally accepted that uniform tension exists at these central cross sections. This has already been found to be the case in a model of the modified British standard. Thus it would only be necessary to alter the moulds now in use to obtain not only uniformity in the comparison of results, but also a real tension test of cement, which these experiments give some reason to believe has never yet been attained under existing conditions, owing to the variable tension at the waist, and the want of correspondence of this variability in briquettes of different patterns.

It is of interest to point out that all forms of cement briquette now in use give a mean stress at rupture which is much less than the maximum tensional stress on the specimen. The contention of many engineers that higher stresses on cement are practicable and desirable is therefore supported by these results.

THE STRESSES IN BUILDINGS.

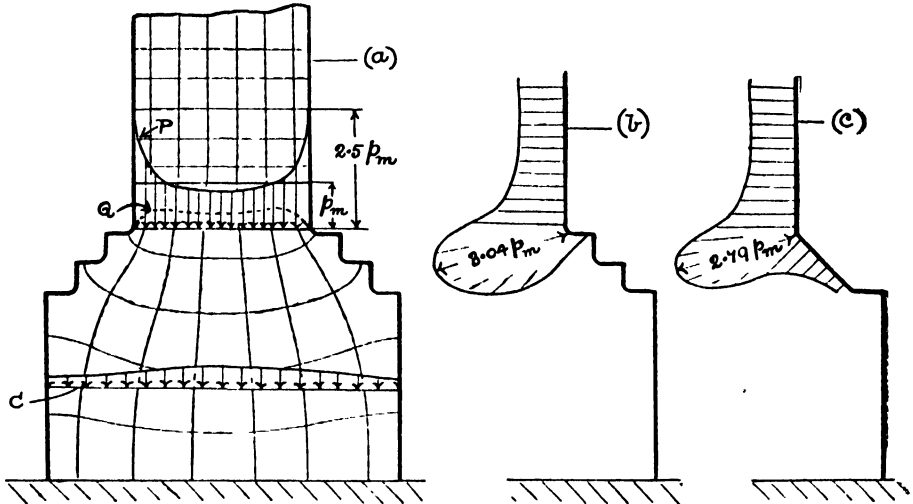
The range and variety of the problems connected with the provision of safe and suitable buildings and structures has recently been forced on the attention of the public in many ways, notably by a lack of housing accommodation all over the country and in London by the insecurity of Waterloo Bridge and the dangerous state of St. Paul's Cathedral. In this post-war period the use of new materials and improved methods of construction for houses have engaged the attention of eminent architects, engineers and firms of contractors.

Commercial buildings, in which great capital interests are involved, have proceeded apace, as in Regent Street, London, and private munificence is supplying the urgent needs of hospitals and educational institutions. Many new technical problems have arisen and will, no doubt, continue to present themselves under a condition of affairs in which methods of construction are changing and new materials are being pressed into service.

Some elementary problems of this kind presented themselves recently during the partial completion of the engineering wing of University College, London, upon foundations built thirty years ago. These difficulties were dealt with successfully as they arose, but the absence of definite data in existing literature led to an experimental investigation on transparent models, described recently in the *Journal of the Royal Institute of British Architects*, in which the stress is measured by photo-elastic means. One of these primary problems is the stress at the junction of a main wall with an enlarged base spread out by footings in the usual fashion to afford a safe load on the earth below it.

It is found from the colour bands that at the first sudden enlargement in such a wall, the stress at the junction of the wall with the footings is very great, as experiments verify. In these experiments it is, however, necessary to avoid

an excessive concentration of stress at such places in order to measure the distribution. All such angles in the model are, therefore, completed by small circular arcs of radius $b/24$, where b is the breadth of the wall. With this modified arrangement it is found that the stress at the horizontal cross-section due to a mean vertical stress p_m rises to approximately $2.5 p_m$ at the junction



FIGS. 39, (a), (b) and (c).—The stress distributions in foundations.

with the wall, Fig. 39a, but is even greater at a point on the circular fillet just below this where it rises to $3.04 p_m$, Fig. 39b. The general vertical distribution of stress P over this cross section is also accompanied by a small variable cross stress Q as indicated, while at the cross-section C well below the change of section, the tendency of the stress is to concentrate towards the centre, as was pointed out earlier in this lecture for another case, and as my colleague, Prof. Filon, has also shown mathematically. It will also be noted from Fig. 39a that in the wall itself the tendency is exactly opposite. Monolithic walls and columns are not usually constructed with stepped footings, but are connected to the base by sloping sides such as may be obtained when the projecting angles of Fig. 39a are removed, as in Fig. 39c. At the junction this is found to result in a diminution of the maximum stress at the face of the wall to $2.79 p_m$. When the footings occur only on one side of the wall we have another interesting case which is dealt with in the paper mentioned above.

Another problem of frequent occurrence is the stress effect due to a line of window openings, and represented here by two rectangular openings with rounded angles, Fig. 40, in a wall of limited width, such as might occur with some modifications and many more windows in a monolithic concrete wall of a building. The stress distribution here shows that at the cross-section A B, the central part of the wall is under practically uniform stress, while the side walls

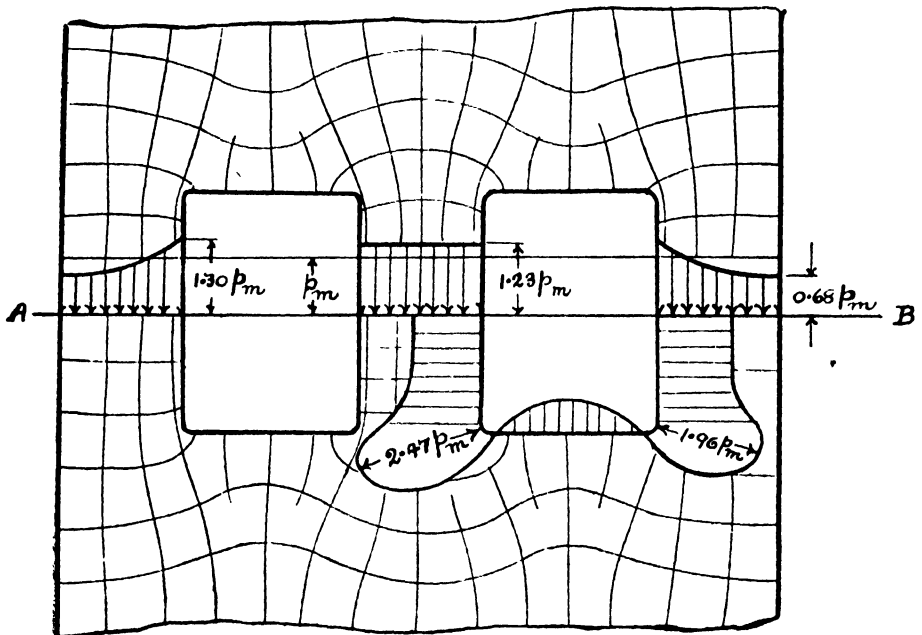


FIG. 40.—The stress distribution in a wall due to window openings.

are under a variable stress with maximum values at the window openings, accompanied by great local concentrations of the stress at the rounded angles, and variable tension along the upper and lower boundaries of the window openings as indicated. This latter stress is unsuitable for masonry, brickwork or concrete to bear, unless reinforced by steel, or, as in a high building, dealt with by a steel framework, which transmits the main load to the foundations, leaving the walls a mere protecting cover of no structural importance.

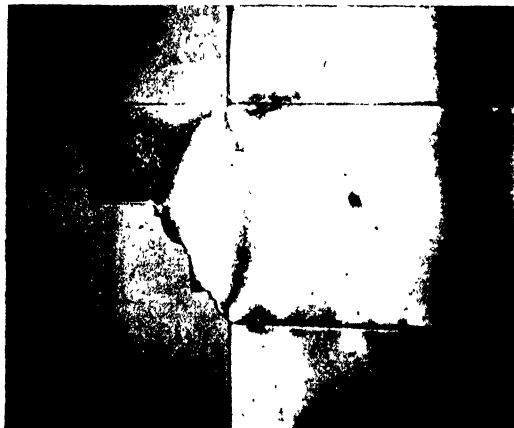


FIG. 41.—The stress distribution in a cornice.

Structural weakness in a building may also be produced by an excess of material placed there from purely artistic considerations, and a good example of this is an ornamental cornice, Fig. 41, such as may be found in St. Paul's Cathedral. The effect of the projecting part is to cause a considerable change in the vertical direction of the lines of stress, as Fig. 42 indicates. Such lines are also found to swell out into the free projecting part and draw attention to

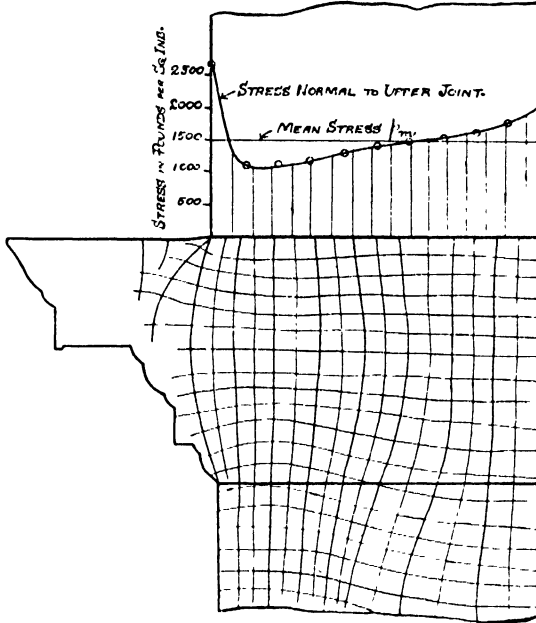


FIG. 42.—Lines of principal stress and normal stress distribution over the joints of a cornice.

the fact that stress exists there. An examination of the stress on the horizontal joints show that there is a great local concentration of load at the face of the wall, which in this case causes an increase of stress of about 75 per cent. of the mean stress at this face, and is approximately the same also at the outermost point in the lower joint. The distribution of stress over the top face of the cornice is also extremely variable, as is shown in this figure. It is substantially the same at the lower joint, thereby proving that the shape of the projection has little influence on the distribution. If, therefore, due to sinking of foundations at one place, a good deal of extra load is thrown on another part of a wall, the extra stress on the cornice at this latter place may rise to so great a value that the material at the face is crushed locally and cracks develop, which may ultimately lead to the cornice falling down, as occasionally happens. The reason for this concentration of stress is not difficult to understand, if it is remembered that in a simple rectangular block of masonry without projections the compression stress is uniformly distributed, and the two horizontal faces approach one another by a small definite amount.

The effect of a projection such as a cornice is to resist alterations of the form of the block, more especially in its own neighbourhood, and in consequence the plane surfaces of the joints deform into slightly curved surfaces, resulting in a higher stress developing at the ends, and more especially at the face of the wall.

This example is one of many instances in construction where an addition of material causes increased stress, which must be taken into account of where architectural or other requirements compel the use of excess material in disadvantageous positions. The experiments of my research assistant, Miss Janet Harris, show that some slight improvement in stress conditions is obtained when the cornice is itself of much less depth than the masonry block.

In the opposite case, where one stone is channelled out to form a rectangular groove, considerable extra stress is thrown on the internal angles.

Whether the discontinuities in buildings consist of additions or subtractions of material of these types, we find, as a general rule, that high stress occurs at such places.

THE ACTION OF CUTTING TOOLS.

The importance of this subject arises from the fact that nearly all modern engineering workshop practice consists of the use of power driven machine tools for removing superfluous material to obtain accurately made parts of machines and structures. It is probable that more than three quarters of all mechanical engineering operations involve the use of cutting tools shaped in various ways, and that millions of machines, operated by skilled or semi-skilled workmen, are in daily use depending entirely on the accuracy and efficiency of the cutting tools employed. With such vast interests involved of users and makers of machine tools, it is not surprising that the precise action of cutting tools has received a large amount of attention, and the technical literature on this special field of engineering is now very large, and is still growing rapidly.

In this connection it may be mentioned that during the past few years a Committee of the Institution of Mechanical Engineers has described a series of investigations on cutting actions which have been made with all the resources modern science is able to bring to bear on this subject. This Committee, in fact, suggested to the lecturer at an early stage of their work that photo-elasticity might be useful in this matter.

The actual machines employed by engineers do not, however, readily permit the use of optical methods of investigation and it was therefore necessary to construct simple modifications of these in order to watch the action of tools working on transparent materials in a beam of polarized light.

One of the simplest of these is a modified planing machine, in which a transparent plate is traversed on a slide by aid of a compound worm gear, so that a fixed tool in a vertical slide rest pares off a shaving from the upper surface, and the framing of the machine is so arranged that the action can be watched by projecting a greatly magnified image on to a screen, as is shown in Figure 43.



FIG. 43.—A planing tool in action.

In this case a steel tool, which has been somewhat blunted by use, is removing the material, not by a true cutting action, but rather by the brutal method of pushing off this upper layer by the wedging action of the tool. The effect of this is to leave the cut surface somewhat rough, as may be noticed by its uneven contour at the edge of the plate behind the tool, and also on the outer edge of the shaving. Moreover, a larger amount of work than is necessary is expended in deforming this cut material by bending it over and out of the way at the point of the tool until it becomes so plastic that light refuses to pass through it. Some recovery from this state takes place and is marked by brilliant colour bands reappearing on the shaving as this photograph shows. In the uncut material near the point of the tool coloured bands are observed in front and behind, which are characteristic and show that the action of the tool produces a variable shear stress, the intensity of which is constant along each band, but is of double the amount on the next inner band until at the black region nearest the tool it is no longer observable owing to the intensity of the plastic state.

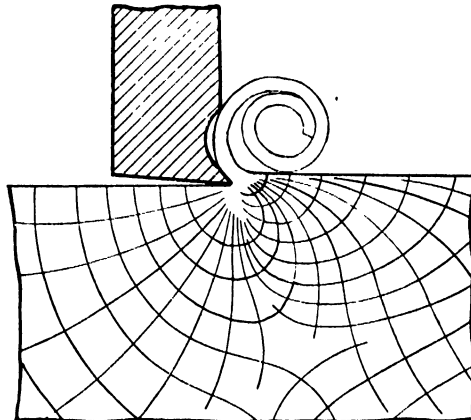


FIG. 44.—The directions of principal stress in a material subjected to the action of a planing tool.

An examination of the directions of stress in the material shows, as may be expected, a somewhat complex state of stress, as indicated in Fig. 44, but when this is examined by the methods described earlier, it is found that for light cuts the action of the tool can be roughly represented as a single force acting in a direction which can be found from the disposition of the colour bands, but varying according to the shape of the tool and the physical properties of the cut material.

A planing machine has the advantage of giving a very simple form of cutting in a straight line, but does not permit of long continued observation such as may be obtained in a lathe where shavings of almost any length may be removed under photo-elastic observation if a disc is cut in a lathe provided with a radial feed. When a cutting tool is used similar in all respects to that already used in a planing machine, but with a good cutting edge, it is found that in both machines quite different action may take place. Provided the angles of the tool are suitable for the work, the material is pared off in a perfectly uniform manner and the colour bands marking the stress remain remarkably steady. The cut surface is also quite smooth and resembles the finishing cut in steel.

If, however, the tool becomes blunt or the angles are not suitable, the cut is a ragged one, the colour bands oscillate violently and the shavings exhibit alternate black and coloured patches as shown in Fig. 45.



FIG. 45.—A badly ground Lathe Tool in action.

All these latter effects appear to arise from one cause. The point of the tool is pushed into the material as a wedge and breaks off a portion, and the intense stress of this section is marked by an immediate expansion of the colour bands

and generally the formation of a crack in advance of the point of the tool, which enables this latter to advance under a lessened resistance and to bend aside the shaving which becomes plastically deformed at the attached end so that no light can pass through it. The further relative movement between work and tool proceeds until it is necessary to push off further material and the process begins anew. The appearance of the shaving under these circumstances is shown by the photograph, Fig. 45, in which this cyclical action gives the more or less periodic marking, while the cut surface has a corresponding irregularity.

A more complicated case is that of the action of a milling machine, in which several cutting edges are acting simultaneously. To study this another machine was constructed by altering the planing machine already described to allow a rotary cutter to operate upon a transparent plate secured to a small table which is advanced uniformly by a worm gear system operated from the

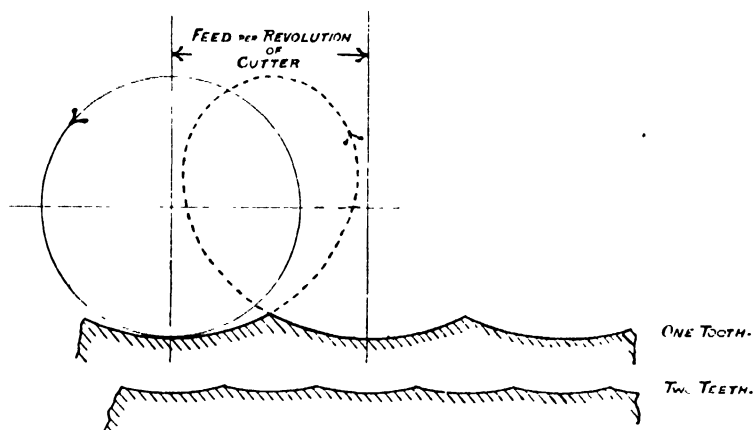


FIG. 46.—Form of the Cut Surface produced by the action of a Milling Tool.

main shaft and actuating the screw feed of the slide rest. It is of interest to note that in this form of cutting action the shaving grows in thickness as the cut proceeds owing to the fact that the path of the point of one cutting edge is a trochoidal curve, Fig. 46, and while the horizontal intercepts between adjacent curves are constant, the radial intercepts increase with the angular motion of the cutter. The surface cut is, therefore, essentially of wave form, as indicated in this figure, and the number of waves in any given length depend on the number and disposition of the cutting edges and the feed.

The final surface produced by a milling cutter operating in a straight line is, therefore, a wave form, approximating, it is true, to a plane when the rotation of the cutter and the feed are suitably arranged, but never quite reaching the ideal flat surface.

As may be expected, the presence of two or more cutting edges operating at one time to remove shavings of gradually increasing thickness is somewhat

complicated. The stress colour bands observed previously with other tools again reappear, but now the stress intensity varies greatly with the depth of cut. Thus in the foremost operating cutter the intensity is very marked as compared with the cutting edge just entering, although the stress systems round each point are similar. At the contour between two cutting edges a point must be reached at which the compression stress caused by an advancing tooth is reduced to zero by the tensional stress caused by the drag of the tooth in advance, and the small black patch on the contour indicates the position of this zero stress. Measurements of the stress distribution at the edge of the plate, Fig. 47, confirm this, and also show how the intensity increases as a cutting edge advances into the material.

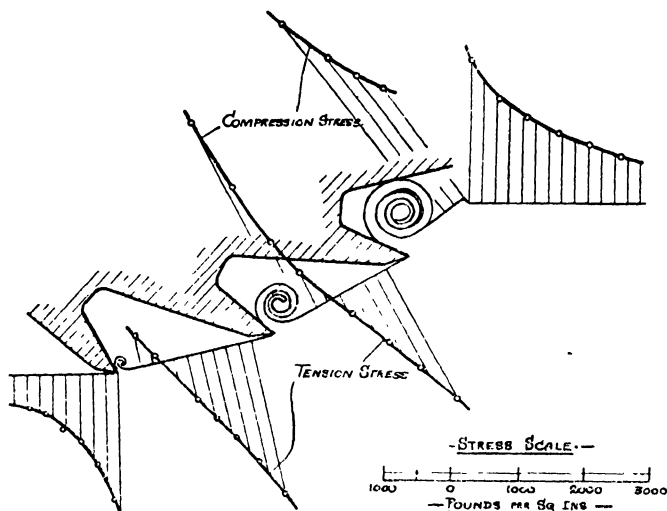


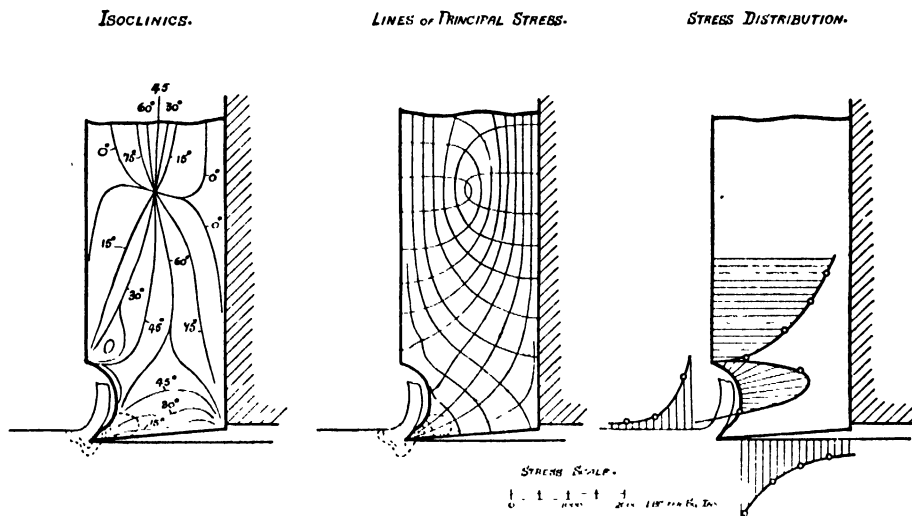
FIG. 47.—Stress distribution at the surface of a material under the action of a milling cutter. The cut surfaces between the cutting edges are shown as straight lines, and the stresses are ordinates to these.

The appearance of the shavings removed is also of interest, since the alternations of light and dark patches show that the material is being wedged off with little or no true cutting action. The cut surface obtained is not, however, found to be so rough as in surfaces operated upon by one cutter and giving a similar action, since the final surface produced is an aggregation of small faces produced at the commencement of the cut when the shaving is thin and the wedging off action is not so pronounced.

Photo-elastic investigation of the action of cutting tools has now reached a stage at which there is a reasonable prospect of further development if certain fundamental investigations are carried out, and in order to show what these are it will be convenient to illustrate the matter by reference to some experiments, which have for their object the measurement of stress in both work and tool.

It has been found impossible up to the present time to maintain the cutting edge of a glass tool for a sufficient length of time to secure measurements of stress in it, and to obtain these latter a modified procedure is adopted in which two tools are constructed of precisely similar shape, one of steel and the other of hard nitro-cellulose or bakelite.

The steel tool is used to make a cut of convenient depth and is suddenly stopped, the tool run back and then replaced by its transparent counterpart, which is then advanced until it is acting in the same manner as the steel tool so far as this is possible, but it is of course impossible to carry the cut further, even when the tool is overstressed, but a fair approximation to the action of the steel tool is obtained, as shown by the colour effects produced and for which stresses can be measured.



In this example the lines of stress have been worked out from the isoclinic bands shown on this Figure, from which the directions of the lines of stress have been determined in the tool and carried to near the point, although not quite. There seems some reason to believe that although the stress near the point of this tool is beyond the yield point the directions of stress are probably nearly correct, if the usual procedure of their delineation is adopted.

When, however, very high stress in the tool is to be determined, there is not the same degree of accuracy in applying photo-elastic laws to the observations, since the photo-plastic behaviour of the material is not accurately known. We are, in fact, in a rather worse position with transparent bodies in this respect than we are with metals, because in the latter case a very large amount of attention has been given to the subject of their plastic behaviour.*

The highest stress registered in this experiment is 4,130 lbs. per square inch. It is probably not a very accurate value, but even then the measurement leaves the stress distribution unsolved at the most interesting part, viz., at the point of the tool engaged with the work.

From these remarks it will be clear that this present bar to any further advance in this direction has to be removed if possible, and for some time past research has been in progress to investigate the photo-plastic behaviour of transparent materials in order to continue this and other work.

This brief description of work accomplished† is probably sufficient to show that photo-elastic research is a means which is fruitful of results, even in so old and well cultivated a field of experimental investigation as that of the action of cutting tools. Photo-plastic research may yield still more.

* "Elasticity and Plasticity," Thomas Hawksley Lecture, The Institution of Mechanical Engineers, November 5th, 1926.

† "An Account of some Experiments on the Action of Cutting Tools," Prof. E. G. Coker and K. C. Chakko, D.Sc., Proceedings of The Institution of Mechanical Engineers, 1922.

"Report on the Action of Cutting Tools," by Prof. E. G. Coker, Proceedings of The Institution of Mechanical Engineers, 1925.

NEW AGRICULTURAL STAPLES IN PALESTINE.

According to a report by the Director of Customs and Trade at Jerusalem, the introduction into Palestine of new staples promising higher acreage results is being organized by the Department of Agriculture, selection being made of crops the production and preparation of which call for no considerable outlay on machinery, and no special expenditure except for labour. Oil seeds, such as ground-nuts, linseed, sunflower and soya beans, and fibres such as cotton, flax and hemp, which find a ready market locally in oil and textile mills, soap factories, etc., are being encouraged. The past season was not favourable from a weather point of view, but good results were obtained at forest nurseries with ground-nuts, flax and sunflowers, where a deficient rainfall was supplemented by irrigation. Banana cultivation is increasing. Subsidiary industries for the production of perfumes, medicinal barks, etc., have been established. Liquorice roots from the Jordan Valley are in good demand.

JOURNAL OF THE ROYAL SOCIETY OF ARTS

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FRIDAY, SEPTEMBER 30th, 1927.

*All communications for the Society should be addressed to the Secretary, John Street,
Adelphi, W.C.(2.)*

NOTICE.

COMPETITION OF INDUSTRIAL DESIGNS.

The following review of the 1927 competition and of the valuable results which are being achieved, is reprinted by permission from the leading article of the *Times* dated September 5th :—

It is now nearly four years since the Royal Society of Arts announced their decision to increase very largely the scope of their competitions in industrial design. The society had found, during many years, much eagerness to compete for the OWEN JONES medals and the small money prizes which the same trust enabled them to offer ; and before they made their new scheme public they had already good reason to hope for its success because they had already received £600 from firms and persons towards the fund for prizes and scholarships. Four years later the success of these competitions is established beyond question. The current number of the society's *Journal* contains the report on the fourth annual competition ; and from the summary of it, which appears in another column to-day, it may be learned that the number of entries was 2,224 and the number of competitors 715, and that " in certain sections the judges report a very marked advance as compared with " the work submitted at previous competitions." The weak spots were furniture, silk fabrics, and carpets, and what the report calls now decorative architecture and now architectural decoration. It seems likely that we not only cannot now make good furniture which is not mere reproduction, but are not going to be able to in the future ; that, bad as much modern architecture is, it will only be worse if we try to adorn it. Unfortunately that is no news. Against it may be set the good work done in tapestry and other fabrics, in pottery and glass, in posters, in printing and book-production (not including illustration), and in wrought iron gates, all of which were better and some much better, than in the previous competitions.

That by itself is good news. It becomes much better news when it is considered together with other news in the report. Of the 745 competitors 571 were students of schools of art. Last year, when the designs for textiles were sent on (in accordance with the practice of the Society) from London to Leeds, three or four young designers were given good permanent appointments with well-known firms on the strength of their exhibits. This year a large number of the prizes offered were provided by firms for designs for special objects ; and some of these firms are so eager to use the winning designs that they insist upon taking them away while the exhibition is still open. In the section of

textiles at least seven firms of manufacturers offered prizes; and in the subsection of carpets five of the prize-winners belonged to Kidderminster. Four firms offered prizes for furniture; nearly twenty printers and publishers were prize-givers for book production; and the Goldsmith's Company gave all the prizes for pottery and glass, many of which were won by young designers in the Potteries. It is true that in the pottery and glass the judges are compelled to deplore "too much evidence of school influence," too little freshness and originality. That is a small set-back against what some will regard as the most valuable achievement of these competitions—the link which they provide between the manufacturer and the art-student. A very short time ago the manufacturer was regarded by the artist as a hide-bound Philistine, who was contemptuous or afraid of all that he suspected to be art; and the artist was regarded by the manufacturer as an unpractical dreamer who had no notion what the public wanted and would pay for. The competitions of the Royal Society of Arts have been not the least powerful among several agencies which have done much to clear up the old misunderstanding. The manufacturer can be fairly sure that, under the terms of the competition, the design that wins his prize will be a practical design as well as a design with beauty in it—that the art of it, indeed, depends upon its fitness for use. And the artists and art-student (still more, perhaps, the art-student's parents) can learn with relief that there is a market for good work, with buyers ready to snap it up and to ask for more. And from this interplay of art and commerce even greater benefits, social and economic, might come than a general improvement of the things in common use.

PROCEEDINGS OF THE SOCIETY.

CANTOR LECTURES.

SOME INDUSTRIAL APPLICATIONS OF ELECTROTHERMICS.

By G. I. FINCH, M.B.E.,

Assistant Professor of Electrochemistry, Imperial College of Science and
Technology.

LECTURE I.—THE PRINCIPLES OF THE CONVERSION OF ELECTRICAL ENERGY INTO HEAT.

(Delivered March 14th, 1927.)

INTRODUCTION.

Electrothermics is that branch of electrochemistry which deals with the conversion of electrical into heat energy and the chemical effects of such electrically generated heat.

The object of the present series of lectures is (i) to elucidate the general principles underlying the electrical generation of heat, and (ii) to illustrate by means of examples drawn from practice the application of such heat and its attendant effects.

Compared with fuel heating, the electrical generation of heat has many advantages, chief of which are:—(i) great temperature range, up to about

* These figures have been arrived at by analysing the working costs of a number of generating stations, as published by various Public Supply Companies in Great Britain. For example, from statistics supplied by the Manchester Corporation Electricity Department for the year ending March, 1920, the following data are available:—

K.W.H. output	..	..	..	..	..	241,000,000
Load factor	..	..	..	..	..	0.252
Ratio maximum demand, Plant installed	..	..	..	..	..	.71

Cost per K.W.H. of net
output d.

[illegible]

Heat can be produced electrically (i) by forcing an electric current through a resistant material or (ii) by the impact of electrically-charged particles, moving under the influence of an electric field, upon matter, charged or otherwise. The generation of heat by the flow of electricity through an electronic conductor is an example of the first method; the heat evolved at the anode of the cathode ray or X-ray tube, or the thermionic valve, or in the electric arc is due to collision of charged particles. It is probable that the mechanism of heat production in an electronic conductor is only a special case of and fundamentally identical with that of the generation of heat by the second of the two methods outlined above.

The derived unit of electrical power is the volt-ampere or watt. The unit of electrical energy is the volt-ampere-second or watt-second or joule. The unit of heat energy is the gram-calorie or cal. The relationship existing between these units is expressed by the equation

$$\begin{aligned} 1 \text{ joule} &= 0.23865 \text{ cal;} \\ \text{hence } 1 \text{ cal.} &= 4.189 \text{ joule.} \end{aligned}$$

For practical purposes these units are, as a rule, inconveniently small, and larger units are employed, those in most common use being the following:—

Unit of power: 1 kilowatt or K.W. = 1,000 watt;

Unit of energy: 1 kilowatt-hour or K.W.H. = 3.6×10^6 joule =
1 Board of Trade Unit; or

B.O.T. Unit or B.T.U. or "Unit" = 859.14 kilogram-calories or Cals.

When dealing with alternating current it is necessary to distinguish between the apparent and effective power in a circuit. The practical unit of apparent power is the Kilo-volt-ampere, or K.V.A., voltage and current being expressed in R.M.S. values. The units K.W., K.W.H., etc., are in practice reserved to designate effective power or energy only.

THE ELECTRICAL PRODUCTION OF HEAT IN OHMIC RESISTANCES (RESISTANCE HEATING).

Liquid and solid conductors may be divided into electrolytic and electronic conductors, according to whether or no the transfer of electricity through them be accompanied by any ponderable quantity of matter. The flow of electricity through both classes of conductors is governed by Ohm's law, and they may therefore be termed ohmic resistances. During the unidirectional flow of electricity through an electrolytic conductor, electrical energy is converted partly into chemical and partly into heat energy. With a unidirectional current flow, a quantitative conversion of electrical into heat energy occurs only in electronic conductors. Towards alternating currents, however, provided the periodicity of the supply be not too low, both classes of conductors behave similarly in that all electrical energy dissipated during the flow of current is wholly converted into heat energy.

When conditions are such that the conversion of electrical into heat energy

in ohmic resistances is quantitative, the quantity of heat, W , produced per second by the flow of electricity in a given system is

$$W = \frac{I^2 R}{4.189} \text{ cal.},$$

where I is the current in amperes and R is the resistance in ohms. Given the absence of heat losses by radiation, conduction, convection, evaporation, etc., the rate of rise of temperature in the system would be determined solely by the heat capacity of the latter and by the current, the ultimate degree of temperature attainable being unlimited. In practice, however, the sources of heat loss indicated cannot be totally excluded, and a state of equilibrium will eventually be attained in which such losses are balanced by the energy supplied to the system. Hence, in any given system the equilibrium temperature will increase with the current. The maximum attainable temperature in a system is, however, ultimately determined by the volatility of the resistor, the evaporation temperature of which may be equalled but, owing to the absorption of heat as latent heat of vaporisation, cannot be exceeded.

The choice of resistor material will thus depend primarily upon the maximum temperature aimed at. Of all solid conductors suitable for the purposes of electric resistance heating, carbon has by far the highest vaporisation temperature, about $3,700^\circ \text{C}$. Its use, however, is not without disadvantages. For instance, liability to oxidation renders necessary the provision of an inert atmosphere; and again, the mechanical strength of the different forms of carbon is such that in order to obtain sufficient robustness of the furnace resistor it must be of large cross section. This necessitates the employment of high currents at low voltages and accordingly results in considerable heat losses and more or less poor efficiencies due to end losses of heat from the resistor ends passing out from the interior of the furnace. Nevertheless, in spite of such disadvantages, carbon in one form or other is, with the exception of carborundum, practically the only solid resistor material suitable for temperatures above, say, $1,200^\circ \text{C}$. For this purpose the use of materials like platinum or tungsten may, on account of their high cost, be ruled out. The maximum temperature conveniently attainable with carbon resistors is in the region of $2,500$, and with carborundum, $2,200^\circ \text{C}$. Above these temperatures, wastage of the resistor, due to slow evaporation, leads to too frequent breakdown. According to J. Richards (*Trans. Amer. Electrochem. Soc.* 26, p. 194; 1914), the vapour pressure of carbon at $2,255^\circ \text{C}$. is equivalent to 0.30 mm. Hg . For temperatures below about $1,200^\circ \text{C}$., various forms of resistance wires are cheaply procurable which, provided they are wound upon supports of which the material is such that it does not corrode the wire at the working temperature of the furnace, resist oxidation and consequently have a long life. Further, the mechanical strength of such metallic wires is such that the resistors can be wound to take power at a high voltage and low current, thus enabling end losses of heat to be reduced to a minimum.

Electrical resistance heating of the charge may be effected in three different ways, i.e., (i) by radiation, (ii) by conduction of heat from the resistor, or (iii) by generating the heat in the charge, the charge itself serving as the resistor. In heating by radiation (radiation heating) the resistor passes through the interior of the furnace, but is not in actual contact with the charge occupying its well or hearth. Heat is thus radiated from the resistor and by reflection from the roof and walls of the furnace on to the charge. In conduction heat transmission, the resistor is either incorporated into that part of the furnace which is in contact with the charge (indirect conduction heating) or is embedded within the charge itself (direct conduction heating). Finally, when a sufficiently conducting charge acts as resistor, the mode of heating may be termed "auto-resistance heating." Of all these dispositions and possible combinations thereof, that in which the resistor is embedded in, and completely surrounded by, the charge is generally the most suitable for processes demanding high temperatures in excess of $1,500^{\circ}\text{C.}$, for the cooler portions of the charge or its reaction products remote from the resistor serve as the effective furnace lining, and the outermost lining may thus be constructed from ordinary refractory materials. When the charge itself serves as resistor, or when the latter is embedded in the furnace lining, or when the heat is transmitted to the charge largely by reflected radiation from the walls and roof of the furnace, then the refractory lining must be capable of withstanding the highest temperatures likely to be attained in any portion of the furnace. Such dispositions of resistor and charge are, therefore, generally only suitable for furnaces intended to deal with the lower ranges of temperature below about $1,500^{\circ}\text{C.}$

A brief account of some of the electric resistance furnaces in technical use will serve to illustrate the above-outlined methods of resistance heating.

(i) *Radiation Heating.* The Baily furnace (Fig. 1) consists of a horizontal, annular trough of refractory material supported by piers above the furnace

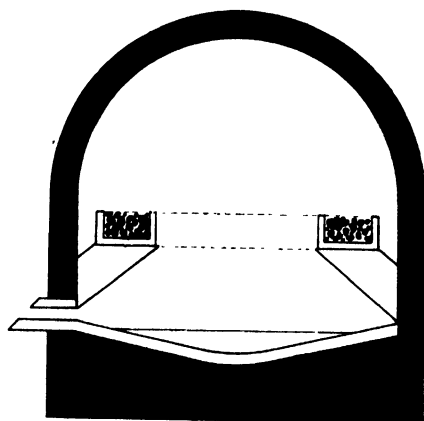


FIG. 1

hearth and containing as resistor fragments of carbon or graphite. Through these current is passed, heating them up to bright incandescence. Heat is radiated directly from the trough and indirectly by reflection from the dome-shaped furnace roof on to the metal charge contained in the hearth. This furnace is used chiefly in the melting of brass, an operation which calls for a uniform heating of the charge. A reducing atmosphere is provided by combustion of the resistor material which, however, being merely of broken fragments, is easily and cheaply renewed.

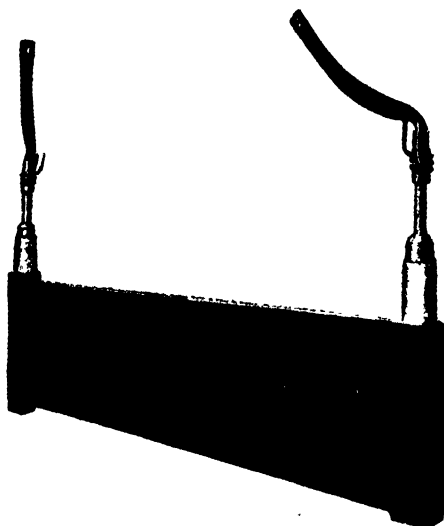


FIG. 2 — Morganite Heating Element for Mounting on Edge, showing Terminals in place.

The Morgan Crucible Company have recently introduced a heating element (Fig. 2) for radiation heating at medium temperatures (up to $1,250^{\circ}$ C.) which consists of a long slab of carbonaceous material protected from oxidation by a thin covering glaze of refractory material. Furnaces heated by this element are being used successfully for, amongst other purposes, the firing of pottery at $1,100^{\circ}$ C. When this process was carried out with coal heating the rejections of finished ware, due to fouling, etc., amounted to 3 per cent. With electrical heating this figure fell to a fraction of 1 per cent., and the saving thus realised more than covered the cost of the electric energy consumed at a price of one halfpenny per K.W.H. Further, the cost of renewing the electrical element was less than the cost of saggars used in coal-fired kilns.

(ii) *Indirect Conduction Heating.* A good example of this type of resistance heating is the Morgan Crucible Furnace (Fig. 3). In its barest essentials it consists of a deep graphite crucible lined internally with a thin layer or wash of non-conducting refractory material. Electrical connection is made to the

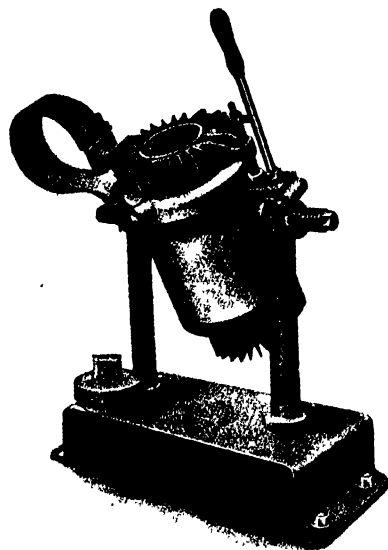


FIG. 3.

top and bottom of the crucible, the passage of the current thus generating heat in the walls of the crucible itself. In order to prevent heat losses, the crucible is embedded in a heat insulating packing. Transfer of heat from the crucible to its contents takes place through the thin refractory lining of the former which also serves to insulate electrically the charge from the graphite portion of the crucible carrying the current. The material and dimensions of the crucible are graded in such a manner that practically all the power is consumed evenly in that portion of the crucible which contains the charge, the bottom connecting lug and upper portion remaining relatively cool.

(iii) *Direct Conduction Heating.* The above-mentioned furnaces are required to operate only at or below the comparatively moderate temperatures demanded in the melting of brass and non-ferrous alloys of a similar nature. There are, however, several electrothermic processes which call for the use of far higher temperatures than can be attained in such furnaces, the refractory lining of which is fully exposed to the maximum furnace temperature. An interesting example of a process necessitating the use of a temperature in excess of $2,000^{\circ}$ C. is that employed in the manufacture of carborundum (silicon carbide)—an important substance extensively used as an abrasive, as a refractory material capable of withstanding high temperatures and as a resistor material. A carborundum furnace (Fig. 4), charged ready for operating, contains a long core, of circular cross-section, consisting of granulated coke. The core is embedded in, and completely surrounded by, the charge of anthracite or coke mixed with sand. Finally, the charge is retained in position by the furnace walls, which are built

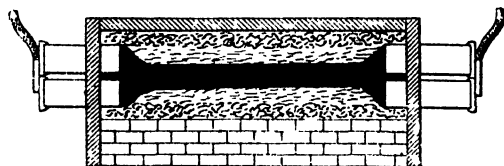


FIG. 4.

of ordinary refractory materials and firebricks. The side walls of the furnace can be easily dismantled to permit of the ready removal of the reaction products. To carry out the reaction, current is passed through the core, the temperature of which rises to about $2,350^{\circ}$ C. The formation of carborundum begins in the layers of coke and sand mixture immediately surrounding the core and spreads slowly outwards. The current is cut off and the reaction interrupted before the outer layers of the charge have been involved. After cooling, the furnace contents are removed, and, by sieving and grading, the carborundum is separated from the unchanged portion of the charge.

(iv) *Auto-resistance Heating*. In this case, where the charge itself acts as resistor, it will be convenient to classify the various types of auto-resistance heating according to the method by which electrical power is supplied to the charge. Three such methods may be distinguished :

(a) Current is passed through the charge from the supply leads which are attached directly to the extremities of the charge (auto-resistance heating with electrode current supply).

(b) Low frequency currents are induced in the charge, disposed in the form of a closed ring, which forms the secondary of an iron-cored transformer (electrodeless auto-resistance heating by low frequency induction).

(c) Eddy currents are induced in the charge which is situated in the field of an inductance coil traversed by high frequency alternating currents (eddy current or high frequency induction heating). Eddy current heating is only a special case of ordinary induction heating, the high frequency of the alternating flux enabling an iron core to be dispensed with.

Of these three types of auto-resistance heating, (a) is suitable only for use with a charge of comparatively high resistance. Otherwise, the low voltage, high current power supply required with a well conducting charge would necessarily result in low thermal efficiencies, owing to excessive end losses of heat through the massive electrodes leaving the furnace. Practical examples of (a) and (b) will be given at a later stage of these lectures, but since high frequency induction heating is one of the most recent developments in electro-thermic practice, it will perhaps be of interest at this stage to discuss more fully this method of electric heating.

If a charged condenser, C (Fig. 5), be connected in a circuit of self-inductance, L, and low resistance, R, an oscillatory discharge will be set up in the circuit, electricity surging backwards and forwards and charging the condenser plates alternately positively and negatively. When R is so low that the oscillations are

only very weakly damped, then the following formula, due to Lord Kelvin, holds with sufficient accuracy:—

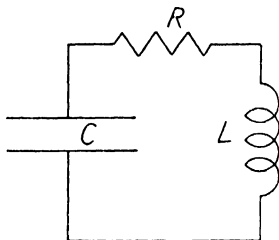


FIG. 5.

$$n^2 = 1/LC$$

where L and C are measured in either true or derived electromagnetic units, and $n = \frac{2\pi}{T} = 2\pi F$, where T is the time of one complete oscillation and F the frequency of discharge. Hence

$$F = \frac{0.159}{(LC)^{\frac{1}{2}}}$$

Further, provided the damping is small, it can be shown that the value of the maximum current flowing in the circuit is given sufficiently accurately by

$$i_{\max} = nCV.$$

For example, consider a condenser of 1 milli-microfarad capacity charged to 15,000 volts and then discharged through a circuit of inductance 0.01 millihenry and of low resistance, say, 0.1 ohm. The frequency is 1.59×10^6 and the maximum current 150 amperes. It will be seen, therefore, that the current in this oscillatory circuit is considerable. Its inductive effect, at a frequency of 1.6×10^6 is equal to that of an alternating current of no less than 5×10^6 amperes at a frequency of 50. A number of experiments can be performed which illustrate in a striking manner the enormous inductive effects of high frequency currents. When approached to an oscillation circuit, an electric filament lamp in a few turns of wire glows; ring discharges occur in a suitably evacuated discharge tube placed in the field of the inductance; finally, a mass of metal, non-magnetic or otherwise, even though it absorbs only a relatively small proportion of energy at each influx of the electromagnetic field, heats up quickly owing to the rapid alternate building up and collapsing of the field caused by the high frequency at which the current oscillates through the inductance. The principle of high frequency induction heating is based on these powerful induction effects. The practical development of this method of electrical heating is due, in the first place, to Dr. E. F. Northrup (*Journal of the Franklin Institute*, 1926, p. 221) and to the Ajax Electrothermic Corporation of Trenton, U.S.A. The licensees in this country are the Electric Furnace Company of London.

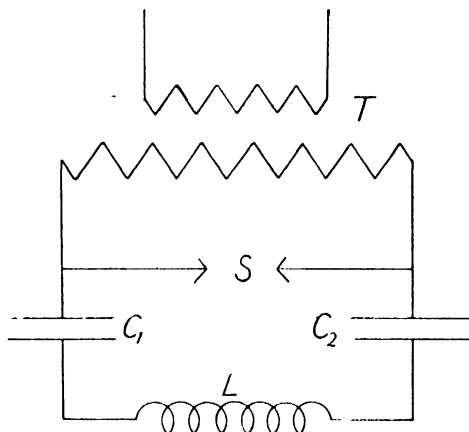


FIG. 6.

In its usual form, the circuit consists of two banks of condensers, C_1 and C_2 (Fig. 6), charged by means of a transformer, T , working off a supply of the usual frequency; the inner plates of the condensers are connected through a spark gap, S , the outer through a single layer coil, L . Since, as we have seen, the currents flowing in this oscillatory circuit are large, all conductors in this part of the circuit should be of heavy multistrand cabling, i.e. of low resistance to high frequency currents, in order to minimise heat losses therein. Inside the single layer coil, A (Fig. 7), which consists of a number of turns of water-cooled copper tubing, is a crucible, C , charged with the metal to be melted. The high frequency resistance of this coil is reduced as far as possible by employing tubing of flattened rectangular cross-section. By correct proportioning of the condenser bank and the inductance coil to suit a given set of conditions, the power factor of the circuit may be made to approach unity. High frequency induction furnace installations up to 35 K.V.A. have been installed and are in successful operation. The Ajax Electrothermic Corporation have also recently developed furnaces up to 100 K.V.A., with a capacity of 600 lbs. of metal, for which current at a frequency of 2,500 or less is generated directly from the usual supply by a motor generator. The power factor of the furnace is naturally low, but is corrected by the use of condensers. Since the induced currents flow mainly in the outer layers of the metal (skin effect of high frequency currents), the choice of frequency will be determined by the internal diameter of the crucible and also by the resistivity of the charge; it varies in technical units from about 500 to 1,000,000 cycles.

High frequency induction heating possesses several important advantages. It can be employed under certain difficult conditions where all other forms of heating would fail, such as, for example, in the heating of the interior metal parts of evacuated bulbs. The most difficultly fusible metals, such as tungsten, can be readily melted. Alloys of critical composition, such as "mumetal," where freedom from contamination by carbon is essential, can be readily

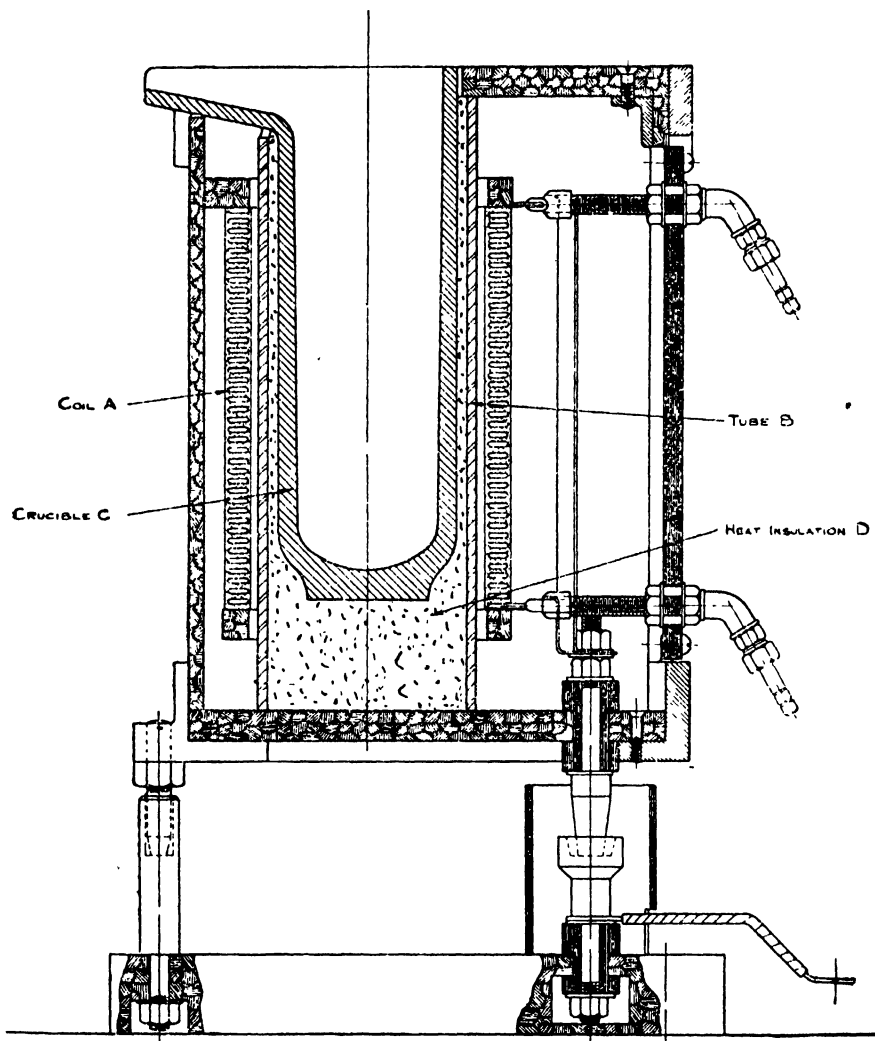


FIG. 7.

prepared. For this express purpose a high frequency induction furnace plant consisting of 42 units, each of 35 to 40 K.V.A. capacity, has been installed in this country at Bilston near Wolverhampton by the Gutta Percha Company. The powerful electromagnetic stirring of the charge ensures perfect mixing and uniformity of temperature throughout the metal.

From the point of view of efficiency, high frequency induction heating compares favourably with that of other types of electric heating. The chief disadvantage undoubtedly lies in the present high cost of the installation, but this will certainly be considerably lowered when the manufacturing costs of special high frequency generators can be reduced with increased demand for

such machinery. The high frequency furnace will, in the near future, undoubtedly play an important rôle in the manufacture of high-class steels. Compared with the crucible process it possesses several important advantages such as absolute freedom from risk of contamination by sulphur from furnace gases, and powerful intimate mixing of the charge. Also, there seems to be no reason why refining of the charge should not be carried out when required.

The efficiency of an electric furnace installation may be regarded either thermally or electrically. By the thermal efficiency is meant the ratio of heat energy usefully employed to the total heat energy supplied electrically to the furnace. The difference between heat supplied and heat used is made up of losses, due chiefly to radiation, convection and conduction of heat from the furnace. In order to minimise radiation losses and convection losses from the walls of the furnace, the furnace design should be such that the ratio $\frac{\text{external surface of furnace}}{\text{volume of furnace}}$ is as small as possible. The corollaries are numerous.

For instance, the furnace should approach spherical shape; the thickness of the walls should be reduced by employing as refractory lining a good insulator of heat; efficiency increases with increasing furnace capacity; finally, the ratio $\frac{\text{volume of furnace}}{\text{load}}$ should be low.

Apart from radiation, the chief source of heat loss is conduction of heat from the interior of the furnace by electrodes; these are the so-called end or electrode losses. This source of loss may be minimised by supplying power to the furnace at as high a voltage as possible and by correct proportioning of the electrodes, which latter point will be gone into more fully at a later stage.

Electrically, the efficiency of a furnace is given by the ratio of electrical energy converted into heat exactly where wanted to total electrical energy consumed. In order to avoid stray electrical losses, the electrical conductivity of the furnace lining should be low at normal working temperatures; otherwise considerable currents may flow through the lining and the heat thus generated is usually valueless. In cases where the electrodes enter the furnace close together, it may be necessary to water-cool the ports in order to maintain a cold, highly insulating ring of refractory material round each electrode. Hartmann, Sullivan and Allen (*Trans. Amer. Electrochem. Soc.* 38, p. 279, 1920) have investigated the variation of conductivity with temperature of several important refractories, with the following results:—

TABLE I.

Material.					Resistance in ohms/cm. ³	
					1000° C	1500° C.
Silica		...	...	...	300,000	8,420
Magnesia		...	...	...	708,000	2,500
Bauxite		...	...	...	17,200	1,100

From the electrical standpoint, however, the furnace installation should be regarded as a whole. This involves a consideration of the nature of the electrical supply and the power and load factors of the installation.

Compared with alternating current, direct current has the following disadvantages: (i) greater generation, transmission and transformation costs, (ii) power regulation by means of resistances involves actual energy losses, and (iii) the possible occurrence of a disturbing electrolysis. In technical furnace operation, therefore, alternating currents only are employed. The use of single-phase alternating currents is usually confined to smaller plants. A three-phase system offers the advantages of lower generation and transmission costs and can be readily transformed into a two-phase supply. Further, from any given three-phase supply two alternative voltages are available. With star-connections, the line voltage is 1.73 times that of the phase voltage; with delta connections, line and phase voltage are equal. Electric furnaces should, therefore, be designed to work off a three-phase (or two-phase) supply; or, should this be impracticable, they should be operated in sets of three (or two) in order to obtain a balanced load on all three phases. Another important advantage of an alternating current supply lies in the ease with which the load to a furnace installation can be controlled without entailing actual power losses, by connecting in delta or star, or by employing various transformer tappings, or by means of an inductance introduced into the circuit.

As the question of power factor is of great practical importance, it will be convenient to discuss it briefly at this stage. In any circuit fed from an alternating current supply, the power at any moment is the product of the voltage and current at that instant. If voltage and current are in phase—which is the case if the circuit contains no inductance or capacity, but only resistance—then the power at any instant is always positive or zero, and never negative. Hence the product of the voltmeter and ammeter readings, being R.M.S., i.e. effective or true values, equals the effective or true power. The introduction of inductance into the circuit, however, causes the current to lag behind the voltage, and a phase difference arises between current and voltage. Consequently, the product at any instant of voltage and current is no longer always positive or zero, but sometimes negative, since at certain moments the voltage and current are of opposite sign. Thus, power surges into the circuit at one moment and back into the generator at the next. The effective or true power will then be equal to the difference between the positive power (A in Fig. 8) passed into the circuit and the negative power (B in Fig. 8) returned to the generator, the latter, together with the corresponding amount of positive power which it neutralises in the total output, being termed the “wattless component.” Thus the apparent power which is the product of the voltmeter and ammeter readings, equals the sum of the effective power and the wattless component. The power factor of the circuit is defined as the ratio of effective power to apparent power. When the voltage

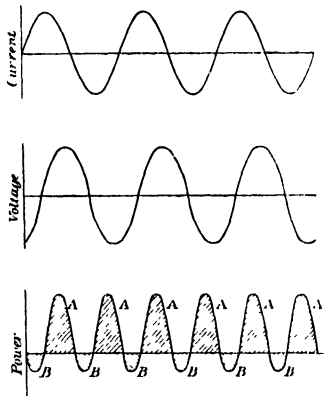


FIG. 8.

and current waves are of sine form, then the power factor is equal to the cosine of the angle of phase displacement, ϕ . The reduction of the power factor by the introduction of inductance into a circuit does not result in a loss of power but merely reduces the power consumption in the circuit and increases the amount of power returned to the generator. Since the current flowing in a given circuit is independent of the power factor, it follows that, for a given power consumption, the size of the generator and of the conductors supplying the circuit must be increased as the power factor decreases. For example, suppose the power actually consumed in a given circuit of which the power factor is 0.5, be 1,000 K.W., then the generating plant will have to be capable of an output of $0.5 \times 1,000 = 2,000$ K.V.A. If, however, the power factor were unity, the capacity of the plant would need to be only 1,000 K.V.A. Thus, although fuel costs remain the same in both cases, a reduced power factor means increased generation and transmission costs. In the case quoted above, the generation costs, other than fuel costs, when the power factor is 0.5 will be nearly double those when the power factor is unity. Since fuel costs are approximately only one third of the total generation costs, it will be realised that a high power factor is a highly desirable feature of an electric furnace installation. Power supply companies often sell electricity to the consumer on a K.V.A. basis. Under such circumstances, the lower the average power factor of the consumer's circuits, the greater will be the proportion of the total power supplied which, although paid for by the consumer, is returned by him to the supply company.

Instead of having, as with the direct current, the relation $E = IR$, we have with alternating current $E = I\sqrt{R^2 + 4\pi^2 n^2 L^2}$; hence $\text{Cos } \phi = \frac{R}{\sqrt{R^2 + 4\pi^2 n^2 L^2}}$. Thus the power factor increases with increasing resistance and decreasing self-inductance and frequency of the current supply. At zero frequency (direct current) the power factor is unity. In designing electric furnaces, inductance

effects are to be avoided. If the winding of a wire-wound tubular resistance furnace runs throughout in the same direction, the self-inductance may be considerable. If, however, half of the wire be wound in one direction and the other half in the reverse, the turns of the latter being closely coupled to those of the first (non-inductive winding), the self-inductance of the furnace will be negligible. Resistance furnaces for alternating current supply can be easily designed and constructed in such a manner that the power factor of the furnace is practically equal to unity. By suitable disposition and, where necessary, interleaving of the supply cables, inductance effects in other parts of the furnace installation can be avoided. Leads carrying heavy currents should be kept away from large masses of metal or the steelwork or reinforced concrete of a building; otherwise eddy currents will be produced therein, resulting not only in a lowering of the power factor but in actual power losses. In extreme cases, carelessness in this respect may cause damage to the steelwork of a building, owing to intensive eddy current heating.

By the term load factor applied to an electric furnace installation is meant the ratio of average power consumption over any given interval of time to the maximum consumption during that time. To be of real informative value, the load factor should be determined over a long period, not less than, say, one year. A high load factor favours low electrical generating costs and low cost of the furnace product, since the interest and most other charges, apart from fuel costs of the generating plant or furnace installation, are practically independent of this factor. In cases where the consumer buys electricity under a maximum demand rate contract, it is especially in his interest to maintain a high load factor in his installation.

THE ELECTRICAL PRODUCTION OF HEAT IN NON-OHMIC RESISTANCES (ARC HEATING).

As distinct from electronic and electrolytic conductors, gases may be termed non-ohmic resistances in that the conduction of electricity through such media is not governed by Ohm's law. The phenomena associated with the flow of electricity through gases may vary widely in nature and appearance. Of the several distinguishable types of electrical discharges in gases, only two will be considered here, namely low and high tension arc discharges.

An object of worship to our forefathers, flame is surely one of the most beautiful of all natural phenomena. No less striking in appearance is its electrical prototype, the arc discharge. In both can be distinguished a similar catastrophic shattering of molecular worlds, due, in the flame, to the release of chemical, in the arc, to electrical energy; in the former, the re-arrangement of the fragments to new systems is haphazard, but in the latter chaos is reduced to some semblance of order under the guiding influence of the electric field.

The Low Tension Arc. The low tension arc may be defined as a stream of ionised gases conveying an electric current across a gaseous gap between two

electrodes, one of which, the cathode, is sufficiently hot to enable it to emit electrons freely. Although our knowledge of the arc phenomena is still far from complete, the following theory, due to Sir J. J. Thomson, undoubtedly affords much insight into the mechanism of the low tension arc and will account, at all events qualitatively, for the known properties of the discharge.

In an arc-stream there exist positively and negatively charged particles. The positive particles are attracted towards and impinge upon the cathode, the temperature of which is thereby raised to a maximum limiting value determined by the vaporisation temperature of the cathode material. The hot cathode emits streams of electrons which are projected into the arc-stream and there give rise to ionisation by collision. A proportion of the positive ions formed re-combine, but others fall into the cathode and thus, by impact, maintain its temperature and electron emission. Similarly, electrons passing into and through the arc-stream, and also formed thermally or by collision therein, travel onwards and strike the anode with great velocity, as a result of which the temperature may rise to a maximum limiting value determined by the vaporisation point of the anode material. In how far the above theory affords a true account of the mechanism of the electric arc will be revealed by a discussion of the properties of, and the phenomena exhibited by, such a discharge. For convenience, a low tension direct current arc burning between carbon electrodes will be considered first. The main features of such an arc are shown in Fig. 9, and are as follows :--(i) the cathode spot which is joined to

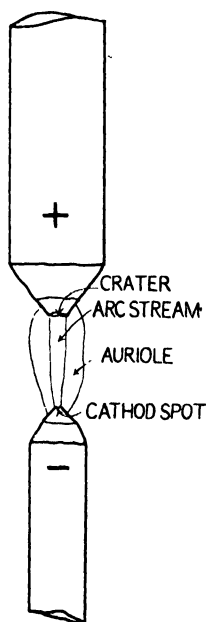


FIG. 9.

(ii) the anode spot, or crater, by (iii) the arc-stream which is surrounded by (iv) the auriolate. According to the theory above outlined, the temperature and hence the electron emissivity of the cathode spot determines whether or not an arc is capable of burning. A low tension arc cannot be maintained unless the cathode spot is sufficiently hot, in the case of carbon, white hot. This electron emission, which is, therefore, a feature of such fundamental importance in the arc, may be demonstrated in a cathode ray tube fitted with a Wehnelt cathode. Experimental proof of the fundamental importance of a sufficiently hot cathode spot is afforded by the fact that an arc cannot be maintained between a cathode consisting of an aqueous salt solution and a carbon anode. By reversing the polarity of these electrodes, however, the seat of the cathode spot is changed from the surface of the cool electrolyte of low boiling point to the carbon electrode, with the result that an arc can be struck which will continue to burn steadily. This experiment is of further interest in that it shows that a hot anode spot is not an essential feature of the arc, although in the ordinary lighting carbon arc the area of the positive crater is far greater in extent than that of the cathode spot, and the temperature is also, as a rule, higher.

The arc-stream consists mainly of the partly ionised, and therefore conducting, vapours of the anode material and carries the current across the gap between the electrodes. The cross-sectional area of the arc-stream varies in such a manner that it is approximately proportional to the current passing. The greenish-yellow auriolate surrounding the arc-stream is formed by vapour which has escaped from the arc and has ceased to form part of the electrical circuit. The arc-stream does not necessarily follow the shortest path between the electrodes, but may be, and, indeed, usually is, deflected to a greater or lesser extent. Such deflections may be due to various causes of which the following are of first importance, extensive use being made of their effects in technical arcs. An arc burning in air between horizontal electrodes is bowed upwards, the deflection being the effect mainly of mechanical causes, i.e. convection currents, but also due, though to a lesser extent, to curvature caused by the field of the arc itself. Both effects are counterbalanced by the magnetism from the current in the electrodes acting as a restraining force and thus preventing excessive bowing which would ultimately lead to rupture of the arc. The purely mechanical convection effect may be heightened by directing upon the arc-stream a jet of air. A comparatively gentle blast will suffice to blow out the arc (blast quenching). In a magnetic field, the arc-stream behaves exactly as does any ordinary flexible conductor. Thus the effect of the field is to force the arc in the direction which will cause the greatest increase in the number of lines of magnetic force linked with the circuit of which the arc forms a part; and if the field in question be sufficiently powerful, the arc may be extinguished (magnetic quenching). Both blast and magnetic quenching are utilised in certain types of industrial arcs, and in some furnaces a magnetic field is employed for directing the arc towards the charge (Fig. 10). In the design of

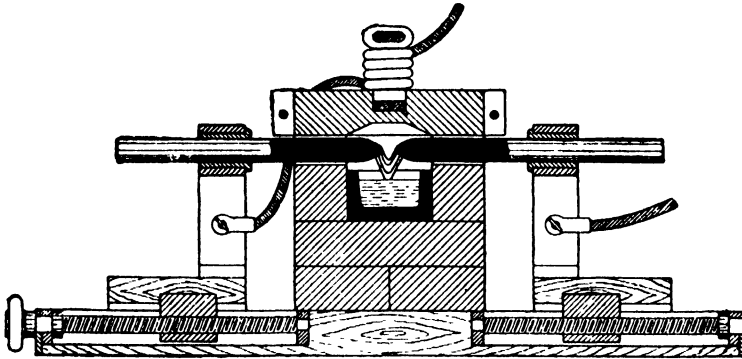


FIG. 10.

electric arc furnaces, the susceptibility of the arc to deflection by stray magnetic fields must be taken into account, particularly in the disposition of power supply leads carrying heavy currents.

A study of the voltage-current characteristic of the low tension arc affords much insight into the behaviour of the arc under different conditions. The characteristic may be either positive or negative—as a rule, the latter. The arc characteristic shown in Fig. 11 is negative, for with increasing current the potential drop between the electrodes decreases. Thus the apparent resistance ($= \frac{\text{potential drop}}{\text{current}}$) of the arc does not remain constant, but falls with

increasing current and tends towards a limiting condition of maximum conductivity, probably corresponding to complete ionisation of the arc-stream gases. It follows that if the current be supplied by a constant source of voltage,

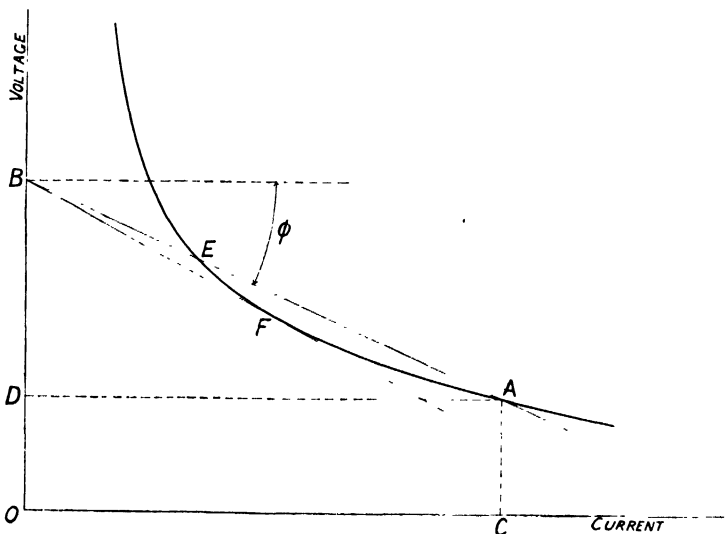


FIG. 11.

the arc must be unstable. Any slight fall in current, due to a variation in some condition affecting the apparent resistance of the arc, will result in a decrease of the degree of ionisation and of temperature of the arc-stream gases, and consequently in a further increase of the apparent resistance of the arc. Thus, since the supply voltage is constant, the arc will be extinguished. On the other hand, a slight increase in current will, for converse reasons, lead to conditions practically equivalent to a short circuit; unless, indeed, the characteristic should, as a result of the heavy current flowing, become neutral or even positive. By including a suitable resistance in series with the arc, however, the discharge may be steadied and rendered perfectly stable. The stabilising effect of such a resistance can be read out of the characteristic. Thus, in Fig. 11, let $AC = OD = v$, the potential drop across an arc of which EFA is the characteristic. Then $OC = i$ is the corresponding arc current. Further, let $OB =$ the supply voltage. Then $BD =$ the potential drop over the resistance in series with the arc. A straight line joining A and B intersects the characteristic in E . Then $\tan \phi$ is numerically equal to the steadying resistance, and it can be shown that the arc is stable only when the condition $\frac{dv}{di} + r > 0$ is satisfied, and that

such is the case only for points on the characteristic to the right of F . F can, however, be shifted to the left, and the range of stable arc conditions thus widened by increasing the value of the steadying series resistance, r , together with the mains supply voltage. In practice, in estimating the value of the stabilising resistance, the resistance of the electrodes and of the leads connecting the latter to the mains are included in the former. In the case of high current industrial arcs the resistance of the electrodes alone is sometimes sufficient to ensure satisfactory stability, for with the currents usually employed the arc

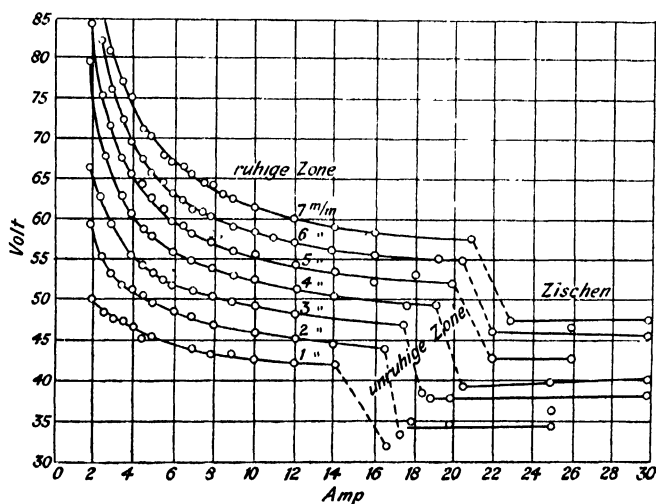


FIG. 12.

conditions correspond to a point on the less steep or nearly horizontal section of the characteristic. The characteristic is affected by various factors, such as the nature of the electrodes, the temperature of the cathode and anode spots and the degree of separation of the electrodes. The last-mentioned factor is the most important. Increase in gap-width results in the characteristic receding from the co-ordinates (Fig. 12). Bowing, curvature or other distortion of the arc-stream virtually amounts to an increase in gap-width.

The potential fall is not uniform throughout an arc; it may be divided into the (i) anode, (ii) cathode and (iii) interelectrode or arc-stream zones of potential fall. The potential fall in any zone can be determined by means of fine wire or carbon probes inserted into the arc-stream and connected to an electrostatic voltmeter. Our present knowledge of the potential conditions of the low tension arc is largely due to a series of classical researches carried out by the late Mrs. Ayrton. The fall of potential in the cathode zone depends on the nature of the electrode; it increases with the current, is independent of the gap-width and nearly so of the gaseous medium enclosing the arc. In the anode zone, the potential fall likewise depends on the material of the electrode, but decreases with increasing current. It is practically independent of the anode temperature. Table II contains values for the cathode and anode potential falls at different electrodes in a low tension arc passing 4 amperes (G. Schulze; *Ann. d. Phys.* 4, 12, 828 (1903)).

TABLE II.

Current = 4 amp.

Gap-width = 8 mm.

Electrode material.					Cathode Fall. Volts.	Anode Fall. Volts.
C	...	...	...	...	10.7	26.3
Fe ₃ O ₄	...	...	...	...	10.1	22.5
Mn ₃ O ₄	...	...	...	...	8.0	18.0
Cr ₂ O ₃	...	...	...	...	9.8	17.0
BaO	...	...	...	...	7.0	7.9
CaO	...	...	...	...	7.8	11.3
MgO	...	...	...	...	9.4	13.0

The potential fall throughout the inter-electrode zone, i.e. along the arc-stream, is uniform except in the immediate vicinity of the electrodes. It decreases with increasing current. C. D. Child (*Phys. Rev.* 19, 117 (1904)) found that in a carbon electrode, low tension arc passing 10 amperes the arc-stream potential fall amounted to 23.4 volts/cm. The total potential drop across an arc can be represented over a wide range and variety of conditions and with a fair degree of approximation by Steinmetz's formula, $v = v_0 + \frac{a(1+b)}{\sqrt{i}}$, where l is the length of the arc and v_0 , a and b are constants. For

carbon electrodes, the constants have the following approximate values: $v_0 = 36$, $a = 51$ and $b = 0.8$. v_0 is equal to the sum of the potential falls of cathode and anode and is the least possible voltage that will maintain an arc.

Of prime interest is the degree of temperature attainable in the arc. The temperature is not uniform throughout the discharge but varies from zone to zone. In the ordinary carbon arc, the anode spot or crater is usually brighter and therefore hotter than the cathode spot, and is the source of highest temperature in the arc as a whole. As previously pointed out, however, the anode temperature may be controlled within wide limits by a suitable choice of the material of the positive electrode and by cooling the same without in any way endangering the existence of the arc. Violle (C. R. 115, 1273 (1892); 119, 949 (1894)) examined photometrically the crater of a carbon arc passing currents between 10 and 1,200 amps. and found that its brightness remained constant throughout and independent of the current. He concluded, therefore, that the temperature of the anode spot equalled the vaporisation point of carbon. Violle estimated this to be about $3,500^\circ \text{C}$. Recent pyrometro-optical measurements, based on Wien's law of radiation, give temperatures of $3,700^\circ \text{C}$. for the positive crater and $3,140^\circ \text{C}$. for the cathode spot of the carbon arc. The latter value, however, only holds good for one given set of conditions, for, unlike the anode temperature, that of the cathode increases with current and the density of the electrode carbon and may, under suitable conditions, attain but not exceed that of the anode spot. Thus it would appear that the maximum temperature attainable at the electrodes of the carbon arc is determined by the vaporisation point of carbon. Confirmation of this is furnished by the results of experiments by E. Benedict (*Ann. d. Phys.* 4, 641 (1915)), who measured a carbon arc crater temperature of $5,600^\circ \text{C}$. in an arc burning under a pressure of 20 atm. Little definite is known of the temperature of the arc-stream, beyond that it (i) is probably considerably lower than that of either electrode spot, (ii) increases with current and gas pressure, and (iii) is uniform throughout the arc-stream except in the vicinity of the electrodes, where it is higher.

The consumption of electrical energy in the arc is given by the product of current and voltage into time. As usually measured, at the busbar ends of the electrodes, this will include not only the energy dissipated in the arc, but also losses due to the resistance of the electrodes.

An important factor in determining the cost of electric arc heating is the electrode consumption. This is due in the main to two causes, namely, combustion and evaporation losses. In the carbon arc, the anode loss may be more than double that of the cathode. In air, the chief cause of wastage is oxidation the effect of which is to round off the end of the anode and to sharpen the cathode to a pointed cone. In a neutral atmosphere, the losses are much smaller and are mainly due to evaporation, the end of the anode presenting a flattened appearance and the cathode being no longer pointed but only

slightly rounded off. Losses occur in a neutral atmosphere even with a water-cooled metal anode, metal particles being torn away from the anode and projected towards the cathode.

Except occasionally for lighting purposes, direct current arcs are rarely employed. The main properties of the alternating current arc can be deduced from a knowledge of the phenomena associated with the direct current arc, the fact that the electrodes now act alternately as cathode and anode being taken into account. The mean or average, as distinct from the dynamic or instantaneous, characteristic of the alternating current arc, is similar to that of the direct current arc. Thus, as in the case of the latter, the arc requires steadying by an external voltage drop varying with the current, which may be provided by either a resistance or inductance coil in series with the arc. An examination of the instantaneous voltage and current curves and of the dynamic characteristics or so-called arc hysteresis curve reveals, however, the important fact that the power factor of the arc is always less than unity. The causes

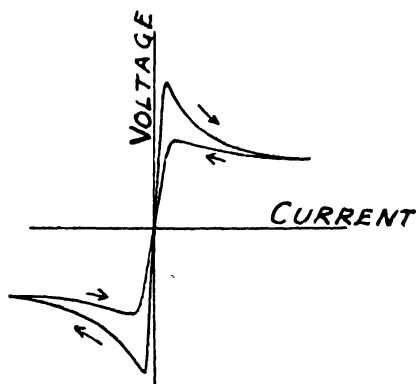


FIG. 13.

operative arc two-fold and will now be discussed. Oscillographic investigations of the voltage and current conditions of the alternating current arc by Duddell (*Electrician*, 39, 637 (1897)), Simon (*Phys. Zeitschr.* 6, 297 (1905)), and others, have shown that the dynamic characteristic during the first half of a half cycle differs from that obtained with the falling voltage of the second (Fig. 13). The result is that for a complete period a doubly-looped curve is obtained and, owing to the resemblance it bears to the well-known curves of magnetisation, the phenomenon is called arc hysteresis. The causes of the phenomenon and its bearing upon the power factor of the arc may be made evident by means of the oscillograph (Fig. 14). The nature of these curves is best explained by considering what goes on in the alternating current arc. At each half-cycle, the arc dies out and current does not begin to flow in the reverse direction until the voltage has risen sufficiently to jump the gap. A sudden rush of current then occurs and, since the arc characteristic is negative, the voltage

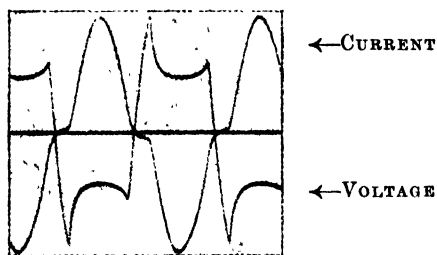


FIG. 14.

drops. Owing to this distortion of the voltage and current curves, the power factor of the discharge falls below unity. It will be particularly noticed that there is no phase displacement between current and voltage, the phase difference of 180° shown in Fig. 14 having been introduced into the oscillograph merely for the sake of clearness. As the time which must elapse after the beginning of a fresh half-cycle before the critical striking potential is reached depends on the temperature of the arc-stream gases, the lag will increase with decreasing frequency; because the gases have more time to cool off before the voltage after each half-cycle rises sufficiently. Thus the power factor of the alternating current arc, unlike that of a circuit including inductance, increases with increase in frequency. A series resistance steadies the arc but lowers its power factor for, by reducing the current, it increases the idle period between successive half-cycles and thus raises the critical striking potential. If the resistance be increased to such an extent that the requisite striking potential equals that of the supply voltage, the arc will be extinguished. With a series inductance, however, steadying of the arc, an improvement of the power factor and the avoidance of power losses are obtained. With a choke, the arc current lags behind the voltage of the supply; consequently, when current ceases to flow through the arc, the line voltage has already reversed and risen to an extent depending on the time during which the current lagged behind the voltage. With sufficient choke voltage, it is thus possible to make the current restart immediately, and so bring the power factor of the arc itself very close to unity. The higher the arc power factor, the greater the efficiency of the arc; but since raising the arc power factor involves, by the introduction of an inductance, a lowering of the overall power factor of the circuit, it will, in practice, be necessary to strike a suitable balance between the two power factors. The power factor of most large scale low tension arcs is, as a rule, high, varying from 0.8 to practically unity. In the second place, a lowering of the power factor may also be due to the current rectifying property exhibited to a greater or lesser degree by most alternating current arcs. It has already been pointed out that a low tension direct current arc cannot be maintained when conditions are such as to prevent the formation of a sufficiently hot, electron-emitting cathode spot. It will therefore be readily understood that, on applying a source of alternating current to two electrodes, one of which is cooled and the

other hot, half-wave rectification of the current will take place and current will pass the arc only when its direction of flow is such that the hot electrode is acting as cathode. The arc is then traversed by a pulsating unidirectional current (Fig. 15). This valve effect has found important industrial application in the shape of the mercury arc rectifier. Complete half-wave rectification, or half-wave suppression, must result in a reduction of the power factor of the arc to at least 0.5. The extent to which the phenomenon occurs depends chiefly upon the temperature and nature of the electrodes. The sudden and violent load fluctuations which sometimes take place in direct arc steel furnaces when melting down cold scrap are not due solely to short circuits, but to some extent also to the arc origin on the hearth contents wandering from cold to hot metal and *vice versa*.

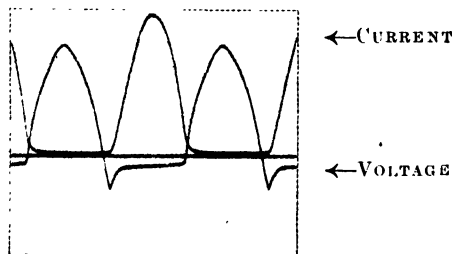


FIG. 15

The High Tension Arc. If the voltage-current characteristic curve of the low tension arc be followed up in the direction of low currents, a region of discontinuity will be encountered where the voltage and current values are erratic and unsteady. On still further decreasing the current by suitably increasing the resistance in series with the arc, together with the external applied voltage, a point will be reached where it is once more possible to obtain steady voltage-current values for the discharge, and a characteristic can be determined which is similar in appearance to that previously obtained with the low tension arc. The new characteristic is that of the high tension arc discharge. The high tension arc may be defined as a stream of ionised gases conveying an electric current across a gaseous gap between two electrodes, one of which—the cathode—is relatively cool. It will be noted that neither in this nor in the previously given definition of the low tension arc is any mention made of voltage; the one and only fundamental difference between the two types of discharges lies in the temperature of the cathode. A hot cathode, as a ready emitter of electrons, is an essential feature of the low tension arc, and under such conditions the cathode potential drop is low, of the order of 10 volts. In the case of the high tension arc the cathode is cool, or its temperature at least so low that the electron emission therefrom is exceedingly sluggish under the influence of a potential fall of the order already quoted for the cathode of a low tension arc. The fall of potential at a cold cathode depends

in the main on the nature of the electrode and the gas with which it is in contact, and is far higher than that at a hot cathode.

TABLE III.

Cathode material.	Approximate values of the cathode fall of potential in volts in			
	Air.	Hydrogen.	Argon.	Water vapour.
Platinum, silver, copper, iron	330—360	300—310	167	450—480
Aluminium, magnesium	200	170—180	69	280—300

The cathode falls of potential for the more electropositive metals are lower than those of the less electropositive and chemically less active metals. This is possibly due to the ease with which the former emit electrons. In the high tension arc discharge, the anode fall of potential is of the same order as in the low tension arc. For most metals it lies between 18 and 24 volts. For both types of discharge it is practically immaterial what the anode temperature may be.

The charged material particles in the low tension arc-stream consist mainly of the vapours of the electrode materials and particularly of the anode, if hot ; and to a far lesser extent of the gas in which the discharge occurs. In the case of the high tension arc, which is usually maintained between water-cooled metal electrodes, the reverse is the case ; charged particles of the atmosphere enclosing the discharge predominate. It may, therefore, be inferred, what in fact proves to be the case, that the potential gradient of the arc-stream under similar conditions of current does not differ much in the case of either the high or low tension arc. It is quite possible to have a low tension arc across which the total potential drop exceeds that of a high tension arc. It would certainly be less misleading to refer to cold and hot cathode arcs instead of high and low tension arcs. As in the case of the low tension arc, the total potential drop between the electrodes of a high tension arc may be approximately represented by the equation $v = v_0 + \frac{a(1+b)}{\sqrt{i}}$; in practice, however,

the value of 1 is usually sufficiently high to enable b , which is as a rule less than unity, to be neglected, and the equation may accordingly be simplified to $v = v_0 + \frac{a}{\sqrt{i}}$. For a high tension arc burning between copper electrodes

in air at atmospheric pressure $v_0 = 350-380$, and, as a rough guide, $a =$ about 100. v_0 is the sum of the electrode potential drops and is the critical minimum potential difference between a pair of nearly touching electrodes necessary to produce a discharge. It is therefore called the minimum striking potential of the arc. The reasons for the different procedures followed in striking

the two kinds of arc will now be clear. In order to start the low tension arc where the supply voltage is seldom greater and usually much less than 120 volts, the ends of both electrodes must first be brought into actual contact with each other. At the point or points of contact, a bridge of high resistance is formed, and the current now flowing raises the ends of both electrodes to a high temperature, and the potential drop at the cathode falls to about 10 volts. On separation of the electrodes, therefore, the current can continue to flow and a low tension arc is formed. The procedure adopted in striking the high tension arc not only differs from this but may be varied to suit circumstances. The electrodes are usually at a fixed distance apart, and to start the arc, it is necessary to apply a voltage which must not only be greater than the electrode potential drops, but also be capable of reducing the resistance of the gaseous interelectrode space, by setting up therein a sufficiently intense ionisation by collision. This total potential difference is usually termed the sparking potential for the particular arc or arrangement of electrodes in question. Once the arc has struck, the resistance of the interelectrode space drops enormously, and the consequent intense rush of current must be checked, partly by means of a choking coil, but mainly by increasing the effective gap-width, and hence also the resistance of the arc-stream, either by suitably quenching the arc or actual separation of the electrodes. Otherwise, the high tension arc will break down into a low tension discharge. In practice, the sparking potential may be reduced in a variety of ways, all of which aim at a reduction of the inter-electrode resistance by ionisation. For instance, hot gases or a flame may be

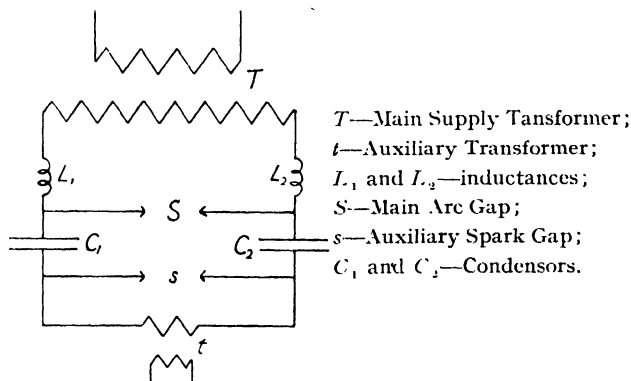


FIG. 16.

introduced into the interelectrode space, or the actual sparking potential may be applied to the electrodes by means of a small auxiliary high tension transformer, *t*, as in Fig. 16. When two similar arcs are burnt in series the total sparking potential can be nearly halved by shunting the one gap with a high resistance, *r*, as in Fig. 17. Practically the whole of the available supply voltage is then applied, first to the open gap and later automatically to the second resistance-shunted gap as soon as the first arc has struck. Further properties of the high tension arc will be discussed at a later stage.

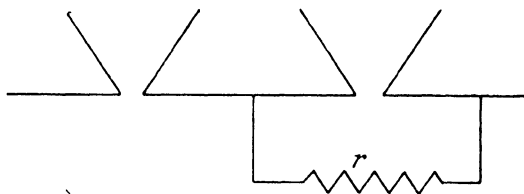


FIG. 17.

In arc heating, the mode of heat transmission depends upon the nature of the charge and the manner in which it is disposed with regard to the arc. Arc heating of gases is essentially a form of auto-resistance heating, the gases actually passing through and forming part of the arc-stream. In the case of solid and liquid charges, three main types of arc heat transmission can be distinguished, i.e. transmission of heat by (i) radiation, (ii) impact by charged particles, and (iii) convection. The first type, also called indirect arc heating, is self-explanatory. Heating of the charge by impact with electrically-charged particles (direct arc heating) occurs when the charge itself acts as one of the arc electrodes. Convection heating by gases leaving the arc-stream takes place when the discharge is completely surrounded by the charge (smothered arc heating), which may be either solid or liquid, but usually the former. It should be noted, however, that in the two last-mentioned cases, both indirect and direct arc heat transmission also take place to a considerable extent.

In the next lectures, the above modes of arc heat transmission will be fully illustrated by practical examples.

GENERAL NOTE.

THE GAINSBOROUGH BICENTENARY MEMORIAL EXHIBITION.—The Gainsborough Bicentenary Exhibition, which will be open at Ipswich from October 7th to November 5th (including Sunday afternoons), will consist not only of the most important series of Gainsborough's own works brought together for many years, but will illustrate the artistic sources from which his inspiration and methods were derived. Important examples of Wynants, Rubens, Van Dyck, Lely, Hogarth and Wilson represent the older masters, whose traditions Gainsborough adopted and so splendidly developed. Works by Cotes, Opie, Reynolds, Hoppner, Hogarth, Crome, Constable, and Cotman will stand for his contemporaries and the successors upon whom the influence of his genius was exerted. While the oil paintings will form the chief feature of the collection, the drawings will constitute an important section, and an attempt will be made to arrange these in chronological order; an experiment not hitherto carried out in any large collection.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, OCTOBER 3.—Chemical Industry, Society of, at the Royal Society of Arts, Adelphi, W.C., 8 p.m. Mr. W. J. Butterfield, "The Gas Industry—Past, Present and Future."

TUESDAY, OCTOBER 4.—Automobile Engineers, Institution of, at the Royal Automobile Club, Pall Mall, S.W., 8 p.m., Major E. G. Beaumont, Presidential Address, "The Influence of the User upon the Automobile Engineer."

Photographic Society, 35, Russell Square, W.C. 7 p.m.
Mr. Oliver G. Pike, "The Highways and Byways of Birdland."

WEDNESDAY, OCTOBER 5.—Analysts, Society of Public, at Burlington House, Piccadilly, W. 8 p.m.

Mr. A. Chaston Chapman, F.R.S., "The Oil of *Centrophorus Granulosus*."

Dr. W. R. Schoeller, and Mr. E. C. Deering, "Investigations into the Analytical Chemistry of Tantalum, Niobium and their Mineral Associates. IX. The Separation of Titanium from Tantalum and Niobium."

Messrs. C. L. Hinton and T. Macara, "The Determination of Aldose Sugars by Means of Chloramine—T, with Special Reference to the Analysis of Milk Products."

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PROCEEDINGS OF THE SOCIETY.

CANTOR LECTURES.

SOME INDUSTRIAL APPLICATIONS OF ELECTROTHERMICS.

By G. I. FINCH, M.B.E.,

Assistant Professor of Electrochemistry, Imperial College of Science and
Technology.

LECTURE II.—ELECTROTHERMICS AND NITROGEN FIXATION.

(Delivered March 21st, 1927).

INTRODUCTION.

It has been stated that the prosperity of a country may be measured in terms of its production of steel and sulphuric acid. But even in a highly industrialised community, such as Great Britain, agriculture is and will continue to be by far the most important of all industries, and the agricultural value of nitrogen compounds is now so well recognised that the nitrogen fixation industry should be held to rank in importance with those of steel and sulphuric acid.

For synthesising nitrogen compounds from atmospheric nitrogen there are in use two methods in which electrothermics play a leading rôle. By the one method, nitrogen is directly oxidised in a high tension arc discharge: by the other, calcium cyanamide, from which other nitrogen compounds may be prepared, is formed by the interaction of nitrogen and calcium carbide, the latter being the product of one of the first electrothermic processes to be successfully established on a large scale. From the electrothermic point of view, discussion of the latter method resolves itself into a discussion of the manufacture of calcium carbide and calcium cyanamide. The conversion of cyanamide nitrogen into other nitrogen compounds is not of immediate interest from the electrothermic point of view.

THE MANUFACTURE OF CALCIUM CARBIDE.

The birth of industrial electrothermics and the successful inauguration of the carbide industry were the outcome of the brilliant researches of Moissan who, in 1892, showed that calcium carbide could be easily prepared in the electric arc furnace. In the beginning, carbide was manufactured for the preparation of acetylene for illuminating purposes. The probable demand, however, was greatly over-estimated, and this, together with the occurrence of several serious acetylene explosions, resulted, towards the end of the century, in a glut of the carbide market.

The raw materials used in the manufacture of carbide are lime and carbon, the reaction taking place according to the equation $\text{CaO} + 3\text{C} = \text{CaC}_2 + \text{CO}$. The question of the purity of the raw materials is important for three reasons : (i) impurities may lead to the formation of troublesome crusts and consequent irregular working of the furnace ; (ii) they are mostly readily soluble in the molten carbide and may lower the value of the product ; (iii) impurities are reduced during the process and thus give rise to a useless expenditure of current. Magnesia and alumina tend to form crusts and increase the viscosity of the melt ; phosphorous and sulphur appear in the carbide as phosphides and sulphides. Phosphide is a particularly undesirable impurity. When acted upon by moisture, phosphoretted hydrogen is formed, thereby increasing the fire risks, due to spontaneous ignition, of storage and transport. Silica is reduced to silicon or the carbide and is, on the whole, the least harmful impurity. The lime, therefore, should not contain more than 4 to 5 per cent. of impurities, and should be of firm texture and not friable. A good anthracite or coke of low ash contents is the usual form of carbon employed. A purer carbon, such as retort carbon or wood charcoal, is generally too expensive. Also, owing to its porosity, charcoal contains much oxygen, and this leads to excessive consumption both of charcoal and electrodes ; but the highest grades of carbide are made from it. In the average charge, about 60 kg. of carbon go to 100 kg. of lime. Calcium carbide is sold on a basis of the volume of acetylene generated from a given weight. Pure carbide (CaC_2) would evolve 349.7 litres/kg. ; an average product yields about 300 litres/kg., corresponding roughly to an 80 per cent. pure calcium carbide.

In all carbide furnaces, the charge is heated by a smothered low tension arc. Three types of furnaces can be distinguished, namely, the discontinuous ingot, the continuous ingot and the tapping furnace ; the first, though now obsolete, nevertheless merits brief description. It consists of a steel truck on wheels, lined internally with carbon (Fig. 18). The current is fed through cables attached to the body of the truck whence it passes through the lining to the molten carbide and thence to a massive carbon electrode suspended vertically above and dipping into the well of the furnace. An arc is thus formed between the surface of the melt and the lower end of the electrode. The furnace is

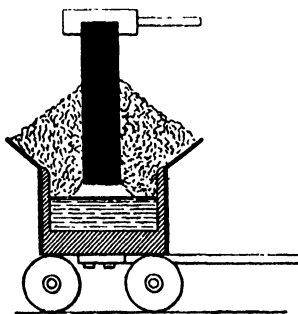


FIG. 18.

filled with the charge, which thus completely surrounds or "smothers" the arc. The advantages of the smothered arc are, therefore, of the same nature as those gained by direct conduction resistance heating, since the refractory lining of the furnace is protected by the cooler portions of the charge and product from exposure to the high temperatures of the actual carbide formation. As the hearth fills, the electrode is gradually raised and kept at approximately the same height above the surface of the melt. When full of carbide, the furnace is removed, the electrode having been raised clear, and the product allowed to cool. The block of carbide is then lifted out, broken up and packed. The disadvantages of this furnace are numerous. Both yield and furnace efficiency are low; the latter about 42 per cent., partly owing to the discontinuous nature of the process and the necessity for allowing the furnace to cool off after each heat, and partly to stray electrical generation of heat through faulty contact of the lining with the furnace shell. The consumption of electrode carbon is high, about 50 kg./ton of carbide, a serious fault in view of the cost of carbon electrodes. The largest units are relatively small, taking 200-250 k.w. at 40-70 volts,

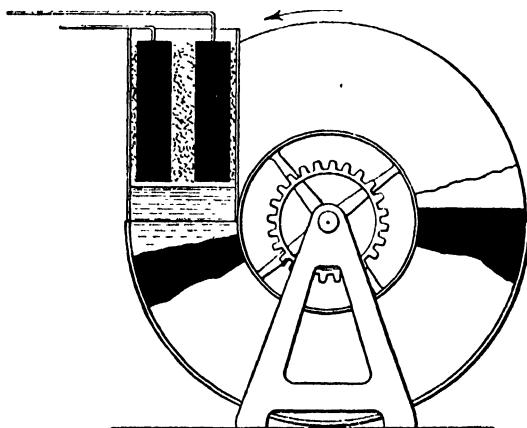


FIG. 19.

and producing a carbide block of up to 400 kg. The product is of high quality, containing about 85 per cent. CaC_2 .

The Horry continuous ingot furnace as used at Niagara is shown in Fig. 19, which is practically self-explanatory. The charge is fed in round the two electrodes between which and the surface of the melt two arcs in series with each other are formed. By slowly rotating the furnace, the level of the melt is kept at a suitable distance from the electrodes. The circumferential section of the shell consists of detachable steel plates which can be removed from that portion of the furnace remote from the electrodes, to enable the cooled sections of the block to be withdrawn. Graphite electrodes are employed, and the electrode consumption is remarkably low, about 3 kg./ton. The product is good and the furnace efficiency high, but repairs and maintenance charges are certainly rather high.

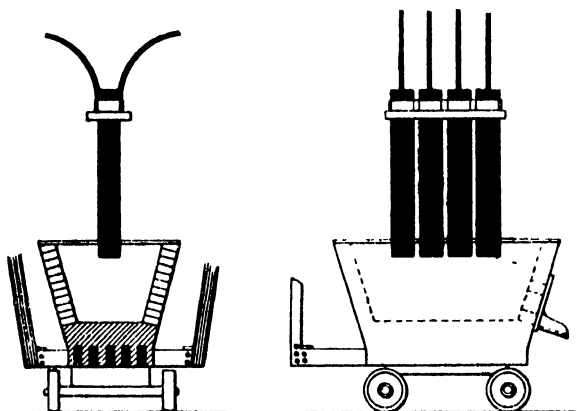


FIG. 20.

Nowadays, by far the greater bulk of carbide is manufactured in continuous tapping furnaces of which the Alby furnace (Fig. 20) may be quoted as a typical example. Though of far greater capacity, it somewhat resembles the discontinuous ingot type of furnace. It is, however, provided with a tapping spout through which the molten carbide is run off at regular intervals. The walls of the furnace are lined with refractory material and the bottom with a bed of a compressed mixture of tar and electrode carbon, making intimate electrical contact with a steel grating to which one lead of the current supply is connected. The smaller units employ single phase currents and have a bundle of four or five vertical carbon electrodes of square cross section clamped together in parallel in the supply. The largest tapping furnaces of the Helfenstein type have no hearth electrode, take up to 12,000 k.v.a., at a power factor of 0.85, and are operated off a three phase supply to three vertical Söderberg electrodes, which is an advantage, at all events electrically. The furnace efficiency is over 60 per cent., about 4,000 k.w.h. being required to produce 1 ton of carbide.

CALCIUM CYANAMIDE.

If Moissan is to be regarded as the founder of the carbide industry, then the honour of resuscitating that industry, moribund in 1899 as a result of injudicious capitalisation and over-production, is due to Frank and Caro. Moissan in 1892 had shown that pure calcium carbide does not absorb nitrogen when heated; Frank and Caro, however, in 1895, made the important discovery that a technical carbide, *i.e.*, an impure calcium carbide containing some 20 per cent. of impurities, will absorb nitrogen with avidity at $1,005^{\circ}$ C., yielding calcium cyanamide according to the equation $\text{CaC}_2 + \text{N}_2 = \text{CaCN}_2 + \text{C}$. The reaction is strongly exothermic, though to what extent is not known with certainty. The heat of reaction is probably about 75,000 calories at $1,000^{\circ}$ C. Calcium cyanamide, also known as "nitrolim" or "lime nitrogen," is a valuable fertiliser; treated with super-heated steam, its nitrogen contents are recovered almost quantitatively as ammonia. Complete and sufficiently rapid absorption of nitrogen by calcium carbide requires a temperature of at least $1,000^{\circ}$ C. The reaction once started furnishes the heat necessary to raise the uncharged carbide to the required temperature. The addition of a few per cent. of calcium chloride or fluoride, possibly because of slight fluxing action, increases the velocity with which nitrogen is absorbed. In actual practice, fluoride only is used; calcium chloride in the spread cyanamide accelerates the formation of dicyano-diamide, a substance harmful to the crop.

The rôle played by electrothermics in the carbide absorption of nitrogen reaction is merely that of supplying the "trigger action" necessary to start the process. The reaction can be carried out in two ways, either discontinuously or continuously. In the former case, the finely ground carbide is charged into sheet-steel drums, along the axis of which a carbon rod, separated by a paper wrapping from the carbide, is situated. To start the reaction, the carbon rod is heated electrically, and the temperature of the carbide immediately surrounding it is thus raised to above $1,000^{\circ}$ C. Nitrogen, obtained by the fractional distillation of liquid air, is then admitted to the drum. Once cyanamide formation has begun, no further extraneously supplied heat is necessary, and the current to the carbon rod is cut off. The reaction then spreads away from the axis throughout the contents of the drum and is completed when the absorption of nitrogen ceases. The reaction mass, after being allowed to cool, is removed from the drum, broken up, ground and finally packed. The reaction may also be carried out in a continuous manner in mechanical furnaces similar in principle to those employed in the burning of pyrites. In this case, however, it is started by means of a low tension arc burning between carbon electrodes situated near the top of the furnace. Nitrogen is passed in at the bottom of the furnace and is met by the carbide which is fed in at the top, and gradually raked down from shelf to shelf by eccentrically bladed rotating sweeper-arms.

ELECTRODES.

This discussion of calcium carbide and cyanamide would not be complete without some reference to the manufacture of the carbon electrodes used in these and other low tension arcs. Electrode consumption is an important item in the cost of all low tension arc processes, and in the carbide industry accounts for about 10 per cent. of the total production costs ; in the steel furnace, however, this figure may even exceed 20 per cent. The two chief electrode materials are carbon and graphite ; the actual choice of either being largely a matter of cost. With graphite, electrode losses are less, and its electrical conductivity is greater than that of carbon ; mechanically, it is also much stronger. Furthermore, the maximum current density permissible in graphite electrodes is three or four times that which can be employed with carbon electrodes. Despite these advantages, however, the high cost of graphite frequently renders its use prohibitive, and carbon is substituted. Morrison (*Chem. Met. Eng.*, 22, 741 (1920)), and Mantell (*Chem. Met. Eng.*, 27, 161, 205, 258, 312, 353 (1922)), have described the manufacture of large carbon electrodes. Anthracite, previously calcined, or petroleum coke, to which retort carbon or electrode carbon scrap may be added, is ground to grain of about 1 mm. diameter which is then incorporated into a semi-plastic mass with a binding material consisting of pitch and coal-tar. The mass is then moulded under high pressure or squeezed through dies of the requisite aperture. The formed "green" electrodes are then subjected to a slow baking process in gas-fired furnaces, the temperature being raised gradually in the course of 10 days to about 1,200° C. The cooling off of the electrodes is an almost equally lengthy process. A too rapid annealing results in unsatisfactory electrodes which, besides being mechanically weak, are also liable to flake off and disintegrate when in use. In the manufacture of graphite electrodes, carbon electrodes are first made by a process similar to the one outlined above, and subsequently submitted to a graphitising treatment. Anthracite carbon is not suitable in this case ; instead, the more expensive forms of carbon are employed, chiefly petroleum or pitch coke. The graphitising treatment of the annealed and finished carbon electrodes consists in a prolonged heating to a temperature of about 2,000° C., carried out under exclusion of air by passing an electric current through the electrodes bedded in granulated carbon and buried in sand. The fall in resistance of the electrodes under treatment affords a measure of the extent to which graphitisation has taken place.

The maximum permissible current density in carbon electrodes is generally put at about 4 amps/cm.², but in practice values up to 10 amps/cm.² are not unusual. Under such conditions, however, so much heat is developed by the flow of current that the electrode, even the portion outside the furnace, becomes exceedingly hot, and it becomes necessary, in order to avoid oxidation losses, to exclude air from that section by means of some form of economiser, such as that illustrated in Fig. 21 (Stobie electrode economiser). The permissible

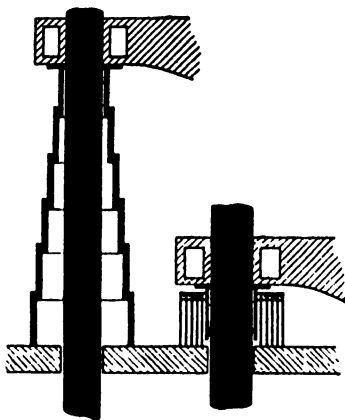


FIG. 21.

current density decreases with increase in cross-section of the electrode ; partly because of the difficulty of avoiding the occurrence of flaws in the manufacture of electrodes of large cross-section, and partly because of the phenomenon known as " skin effect," *i.e.*, the tendency of alternating currents to flow chiefly through the outer layers of a conductor of large cross-section, carbon electrodes are made up to 36in. in diameter. Such large sizes, however, are exceedingly unwieldy and call for great care in handling if breakages which may entail serious consequences are to be avoided.

Sufficient has been said to indicate that the manufacture of carbon, and still more so, of graphite electrodes is a lengthy and costly process. The recent introduction by Söderberg (*Trans. Amer. Electrochem. Soc.* 18, 351 (1920) ; *Chem. Met. Eng.*, 26, 1178 (1922), and 29, 865 (1925)), of a new and highly successful type of electrode, which obviates the necessity of employing high grade materials coupled with a lengthy and expensive electrode-making process, may therefore be hailed as one of the greatest, if not indeed the greatest, advance made in the whole field of electrochemistry within the last twenty years.

The Söderberg electrode (Fig. 22 and 23)*, is a continuous self-baking electrode consisting of sections of sheet-steel tubing, fitted together as required, into which unbaked electrode material is rammed or even simply poured. The mixture contained inside that section of the electrode within the furnace is baked by the waste heat of the latter, the gases escaping through perforations in the steel tubing. The tube is fitted with radial fins or ribs (Fig. 24), directed inwards, which serve to hold the baked section of the mixture and also increase the area of electrical contact between the latter and the steel tubing. When, in the normal course of events, the electrode requires lengthening, this may be effected without interrupting furnace operations by fitting a fresh section of

* The illustrations shown of Söderberg electrode are by courtesy of the Electric Furnace Company, London, who are the sole agents in this country.

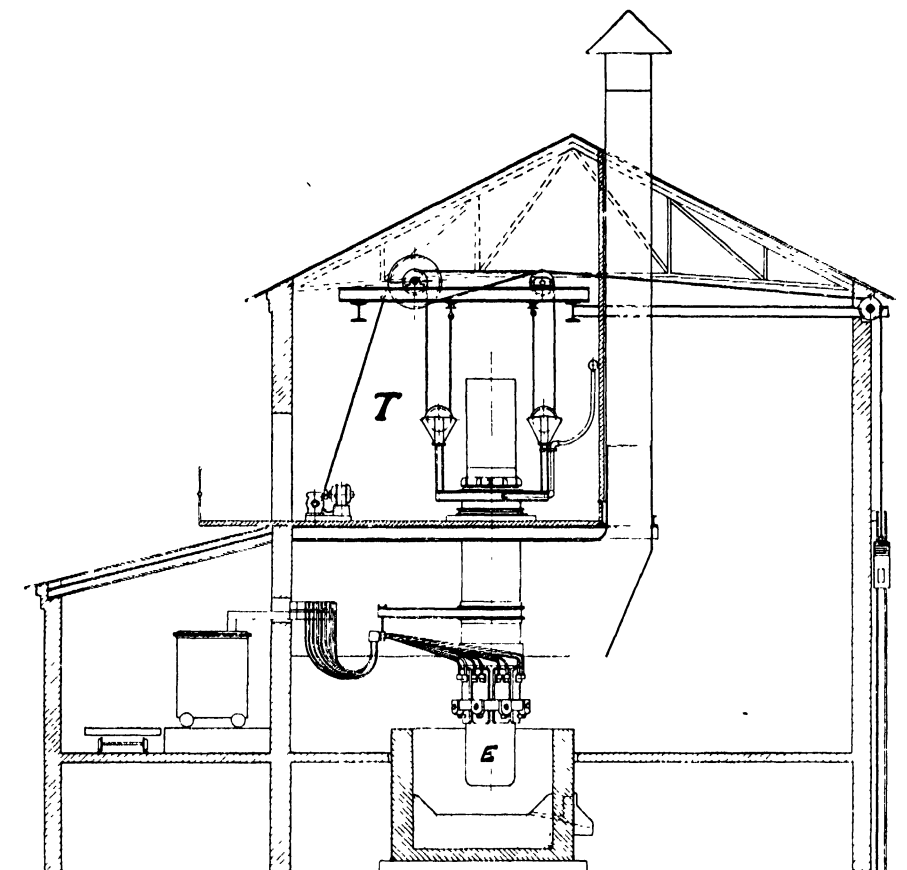


FIG. 22.—Section through a Carbide Furnace Installation, with Söderberg Electrode.
E—Electrode; *T*—Tamping Cabin.

tubing on to the end of the electrode protruding from the furnace and ramming or pouring it full with fresh electrode mixture. Since the conductivity of the "green" electrode mixture is very low, most of the current in the cooler sections is carried by the steel tubing and fins. As the electrode descends into the furnace, more and more of the current flows through the mixture, according to the degree to which the latter has been baked. The steel tubing melts away a short distance above the furnace end of the electrode, leaving the completely baked electrode mass free. While space does not permit of a more detailed account of this epoch-making invention, it will be of interest to enumerate the more outstanding advantages of the Söderberg electrode.

In the first place, the consumer makes his own electrodes and is, therefore, independent of the electrode manufacturer. The necessary anthracite calcining, grinding and mixing plant for preparing the green electrode mixture is robust, simple and easily run. Calcining is carried out in a continuous smo-

thered arc-heated kiln (Fig. 25). Electrode consumption is reduced, owing to the complete absence of butts and breakages, and to the high degree of density of the baked mass, which is due to the fact that baking goes on under the pressure of the weight of the upper unbaked contents of the electrode. Further, the electrode is well protected against oxidation. Economies in electrode consumption costs varying from 50 to 80 per cent. have been reported in favour of the Söderberg electrode. The maximum current density permissible is

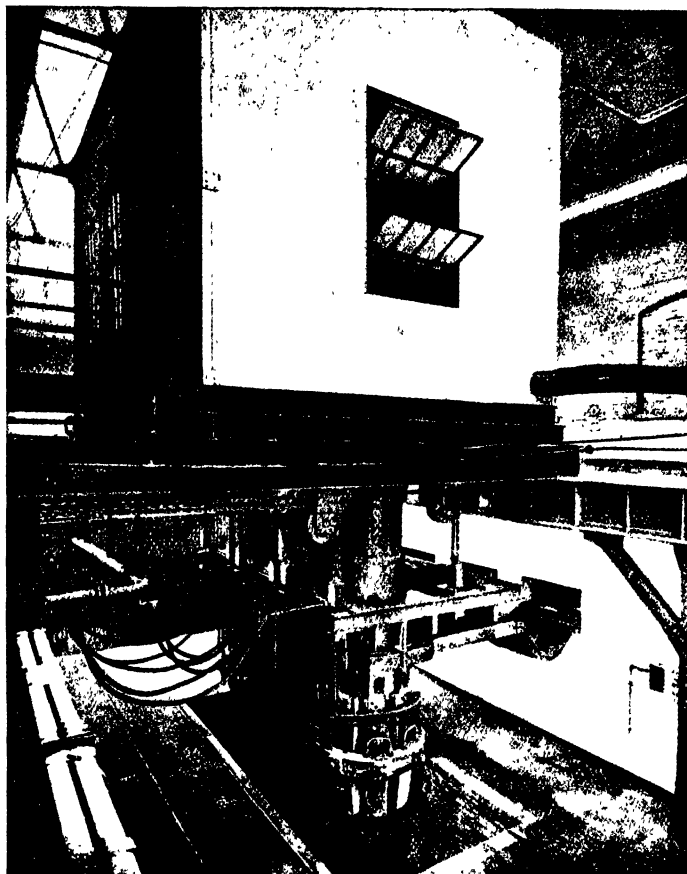


FIG. 23.—Soderberg Electrodes in a Carbide Furnace of 12,000 K.V.A.

high, exceeding 12 amps/cm.². The largest Söderberg electrode at present in use has a diameter of 83 inches, but there seems to be no reason for supposing that this represents a limit. Such electrodes, contrary to the larger sizes made of carbon or graphite, are robust and can be easily and safely handled without fear of breakages. Hitherto, the size of arc furnaces has been restricted mainly by the dimensions of the carbon electrodes available. The introduction of the Söderberg electrode has already led to a great increase in the capacity of

carbide and ferro-silicon furnaces, and will, in the near future, in all probability render a similar service to the electric steel furnace. A carbide or ferro-silicon furnace with Söderberg electrodes can be operated continuously at full load with no stoppage for change of electrodes, and when the necessity arises for raising the holders, this can be done by loosening and slipping them up the electrodes, full load being maintained throughout. That this is possible is due to the clean surface and resilience of that portion of the tubing containing the unbaked electrode paste. With carbon or graphite electrodes, such a procedure would inevitably result in disaster. The difficult problem of the collection of the vast quantities of carbon monoxide generated as a by-product in the manufacture of calcium carbide is greatly facilitated by the use of the Söderberg electrode. •

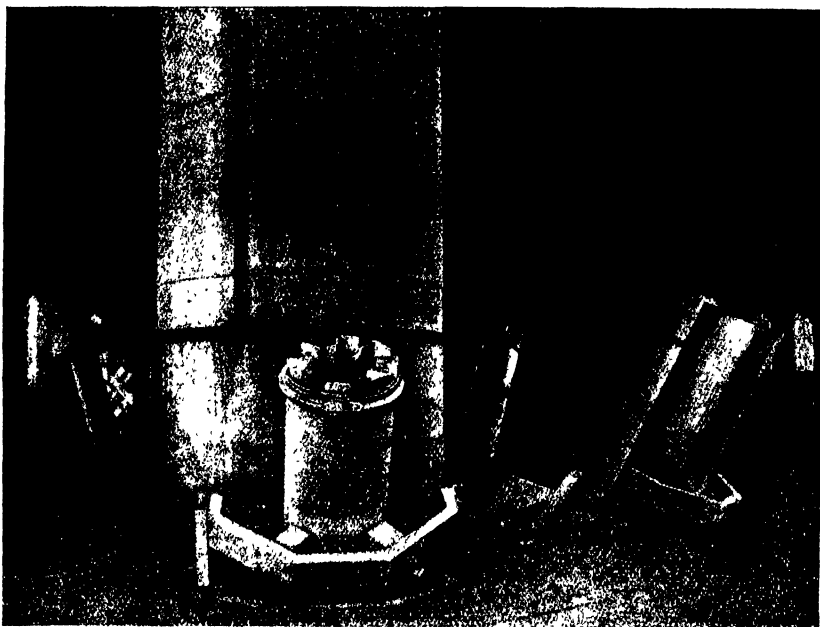


FIG. 24.—Tamping-Floor for Söderberg Electrodes, showing radial Fins.

Söderberg electrodes taking over 350,000 k.w. are in use in Europe, U.S.A., Japan and in the Dominions. So far, none have been installed in this country. No doubt, however, the revolutionary nature of this invention will, in course of time be recognised here. Söderberg electrodes up to 83 inches in diameter have been successfully employed in carbide, ferro-silicon, ferro-manganese, steel and pig-iron furnaces and in aluminium electrolysis.

Conduction of heat from the interior of a furnace by protruding electrodes or resistor ends may account for a considerable proportion of the total heat losses of an electric furnace. Such losses may conveniently be termed "electrode losses," and "end losses," in the case of arc and resistance furnaces respectively.

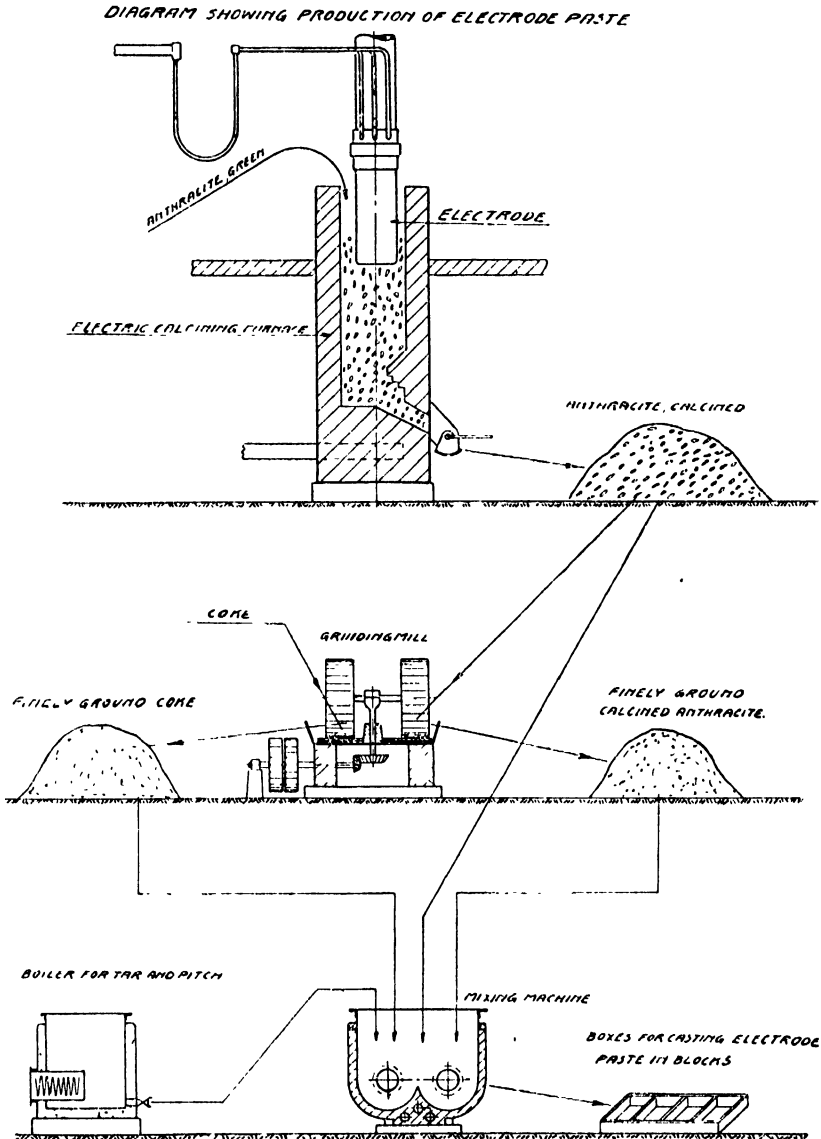


FIG. 25.

Induction furnaces, being electrode-less, are free from this source of loss, and their thermal efficiency is in consequence exceptionally high.

The higher the voltage of the power supply to a furnace, the lower will be the current required for a given power input, and hence the smaller the necessary cross-section of the electrode. Since a good conductor of electricity is also a good conductor of heat, it follows that the end or electrode losses from a furnace consuming power at a given rate will decrease with increase in voltage of the

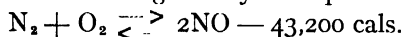
power supply. In the case of wire-wound resistance furnaces, it is, thanks to the mechanical strength of the resistor, generally feasible to construct the furnace to take power at a comparatively high voltage and thus reduce end losses to a negligible quantity. Where, however, owing to the nature of the resistor material, a small resistor cross-section is out of the question, or where, as in the case of low tension arc furnaces, the supply voltage must necessarily be low and is variable only within comparatively narrow limits, the resistor or electrode cross-section must be large, and the end or electrode losses will be considerable. Consider, for instance, a carbon electrode of a low tension arc furnace. Part of the electrode lies within and part without the furnace. The power supply cable is attached by means of a water-cooled collar or clamp to that section of the electrode which is external to the furnace. From the thermal as well as the electrical point of view, the effective length of the electrode is measured from the water-cooled clamp to the end within the furnace. Now, the electrode not only conducts heat away from the furnace, but also dissipates both into and out of it the heat generated by the passage of the current throughout the electrode itself. The latter, the electrical heat losses, will decrease with increasing cross-section; the former, heat conduction losses, however, will decrease with decreasing cross-section of the electrode. Hering (*Electrochem. Ind.*, 7, 442, 190, *Met. Chem. Eng.*, 8, 471 (1910); *Trans. Amer. Electrochem. Soc.* 17, 171 (1910), has shown, however, that, from the point of view of minimising electrode losses, the necessary compromise between these conflicting conditions is effected when the proportions of the electrode are such as to comply with the equation

$$\frac{a}{l} = I\sqrt{\frac{r}{2k\theta}}$$

where a = cross-section of electrode in cm^2 , l = length in cm ., I = current in amperes, r = specific resistance of the electrode material in ohms/cm^3 , k = thermal conductivity in joules and θ = the temperature difference between the electrode ends. The length, l , is chosen as short as practicable, the supply voltage as high and the current consequently as low as possible.

THE DIRECT OXIDATION OF ATMOSPHERIC NITROGEN.

The direct oxidation of nitrogen may be represented by the equation



Thus the reaction proceeding from left to right is strongly endothermic, and energy in some suitable form must be supplied to a mixture of nitrogen and oxygen before combination can occur. The foundation of that vast and growing branch of the nitrogen fixation industry which is based on the direct oxidation of atmospheric nitrogen was laid by Cavendish who, as far back as 1781 effected the synthesis of nitric acid by burning hydrogen in air, and in 1784 observed that nitrogen was oxidised when a high tension electrical discharge

passed through air.* Cavendish thus shewed that the energy required for the combustion of nitrogen could be supplied either chemically or electrically.

Nernst and his co-workers Jellinek and Finckh (Nernst "Die theoret. u. experim. Grundlagen des neuen Wärmesatzes," 1918, p. 118), investigated the equilibrium conditions and arrived at the results tabulated below.

TABLE.

T° abs.	t ₁	t ₂	Per cent. No. by volume at equilibrium.
1500	1.26 days	3.30 mins.	0.10
1700	59 mins.	14.8 secs.	0.30
1900	2.08 "	0.9 "	0.40
2100	5.06 secs.	7.25×10^{-2} secs.	0.75
2300	0.26 "	5.04×10^{-3} "	1.25
2500	1.06×10^{-2} secs.	3.46×10^{-4} "	1.76
2700	5.25×10^{-4} "	2.35×10^{-5} "	2.37
2900	3.45×10^{-5} "	2.01×10^{-6} "	2.88
3100	1.86×10^{-6} "	1.35×10^{-7} "	3.45

In the above table t₁ is the time required at T° abs. for the formation of half the possible equilibrium concentration of NO from air at atmospheric pressure ; and t₂ is the time required for the decomposition of half a given quantity of pure NO. It will be seen that, at the highest temperatures, the rate of attainment of equilibrium between nitrogen, oxygen and nitric oxide is exceedingly rapid, whilst at temperatures below 1500° abs. the rate of decomposition of NO is sufficiently slow to be negligible in practice. By further extrapolation up to a temperature of 3,750° abs., the supposed temperature of the electric arc, the equilibrium concentration of NO was estimated to be 7 per cent. by volume. Earlier experiments carried out by Muthmann and Hofer, McDougall and Howles and by Brode, who burned high tension arcs in air, had resulted in similar concentrations of nitric oxide being obtained. Nernst, therefore, concluded that the oxidation of nitrogen in the arc was a purely thermal reaction. The results of later investigations by Grau and Russ, and le Blanc and Nüranen afforded, in the main, additional support for this view. Thus it would appear that the most favourable conditions for the synthesis of nitric oxide would be realised by heating air to the highest possible temperature and subsequently chilling the hot gases as rapidly as possible to below 1500° abs.

It was later shewn, however, by Haber and Koenig (*Zeitsch. f. Elektrochem.* 13, 725 (1907) ; 14, 689 (1908)), that the purely thermal explanation of the formation of nitric oxide in the electric arc cannot account for the striking

* Actually, Priestley was the first to synthesise nitric acid. He showed that electric sparks passing in air produced an acid which he, however, mistook for carbonic acid.

experimental results obtained by these investigators when employing specially cooled arcs, the temperatures of which certainly did not exceed $2,500^{\circ}$ abs. In their experiments Haber and Koenig circulated a slow stream of oxygen-nitrogen mixtures through cool arcs under a reduced pressure. No steps were taken to ensure rapid chilling of the gases leaving the arc. Starting with air, a final concentration of 9.8 per cent. nitric oxide was obtained. With an approximately "inverted air" (81.7 O_2 , 18.3 N_2) the equilibrium concentration of nitric oxide rose to 12.1 per cent. For two distinct reasons these values show that the purely thermal theory is incapable of truly representing the facts of nitric oxide formation in the arc. In the first place, according to Nernst's values for the thermal equilibrium, a yield of 9.8 per cent. nitric oxide corresponds to an absolute temperature of $4,300^{\circ}$, and 12.10 per cent. nitric oxide to one of $5,000^{\circ}$, whereas the temperature attained in Haber and Koenig's arcs certainly did not exceed $2,500^{\circ}$; and secondly, the yield of nitric oxide was found to be greater with "inverted air" than with ordinary air, whereas if the thermal explanation were the true one, the yield should have been the same in both cases. Haber and Koenig approached equilibrium from both sides and in all cases obtained similar equilibrium values. They therefore, concluded that they were dealing with an "electrical equilibrium," differing from the thermal in that the concentration of nitric oxide at equilibrium was governed, other conditions being equal, by the rate of dissipation of electrical energy in the system, the value of which was a measure of the deviation of the electrical from the thermal equilibrium. The value of the ratio of the electrical to the thermal equilibrium constant depends on the decomposition velocity at the particular temperature in question; it will, therefore, decrease with rising temperature. Haber and Koenig's experimental results and the conclusions drawn therefrom thus afford a satisfactory explanation of the apparent support which the work of previous investigators had given to the thermal explanation of the nitric oxide equilibrium. With high arc temperatures, the gases in electrical equilibrium on leaving the arc, i.e., the zone of electrical equilibrium, are themselves so hot that in the absence of all electrical influences rapid decomposition of nitric oxide occurs until the concentration of nitric oxide corresponds with that of the thermal equilibrium value. Thus, in the case of the normal, i.e., not specially cooled arc, the electrical equilibrium is in effect masked by the thermal equilibrium.

From the point of view of cost, electrical energy is the most important raw material in the arc processes of nitrogen fixation. The cost of air, the other raw material essential to the process, is merely that of the relatively small plant charges and power required for circulating the same throughout the plant. The efficiency of an arc nitrogen fixation process is, therefore, primarily to be expressed in terms of output of combined nitrogen for a given input of electrical energy. Haber (*Thermodynamics of Technical Gas Reactions*, p. 269), assuming a probable arc temperature of $3,200^{\circ} \text{ C.}$, and thermal equilibrium conditions, has

calculated that, in order to produce 315 grams of nitric acid, a total of 2,898,400 cal. are needed. This corresponds to a theoretical yield of 93.5 grams of nitric acid per K.W.H. The yields actually obtained in modern arc nitrogen fixation installations average between 50 and 60 grams of nitric acid per K.W.H., corresponding to a *furnace efficiency* of from 53 to 64 per cent., assuming the mean arc temperature to be 3,200° C. At first sight it might thus appear that, considering the high temperatures involved, the technical arc process is remarkably efficient. This is, in reality, far from being the case. Of the 2,898,400 calories required to produce 315 grams of nitric acid, no less than 2,790,400 are employed solely in heating up the necessary volume of air, and only 108,000 really usefully employed in furnishing the energy actually absorbed in the formation of nitric oxide. Thus, in practice, it is found that only about 3 per cent. or even less, of the energy dissipated in the arc produces nitric acid, and this low value represents the *process efficiency*. Of the remaining 97 per cent., approximately 18 per cent. could be reconverted into electrical energy and resupplied as such to the process. But the gain in efficiency thereby attained would be small. The objections to efficient heat recuperation between exhaust and intake gases are numerous. For one thing, attempts at such efficient heat recuperation would at once result in a lowering of the yield on account of the slow rate of cooling of the arced gases. In practice the rapid cooling of the reaction gases, shewn by Nernst and his co-workers to be so essential, is for the most part attained by the mixing of the arced gases with cold "false" air which does not come into contact with the arc itself. Holwech and Koenig (*Zeitsch. f. Elektroch.* 16,809 (1910), using cool arcs obtained a yield of 80 grams of nitric acid per K.W.H., and it would thus seem that one possible way of improving the present remarkably poor efficiency of the arc process may lie in the direction of the use of cool arcs. The practical difficulties are, however, formidable.

It should not be overlooked that, in addition to that of the yield as discussed above, there is another aspect of the process which has a direct and important bearing upon the cost of nitrogen fixation by the arc, namely that of the concentration of nitric oxide in the arced gases. In technical practice this lies between 0.8 and 2 per cent. The recovery of such highly diluted nitric oxides involves the use of a large and expensive tower absorption system, even when a 90 per cent. efficiency in recovery is held to be sufficient, as is usually the case. Both the ease and overall efficiency of recovery increase rapidly with the concentration of the nitric oxides, contained in the arc gases. Haber (loc. cit.), succeeded in obtaining an equilibrium concentration of 10 per cent. nitric oxide, though at the expense of a poor yield per K.W.H. Thus there are good experimental grounds for believing that, from the point of view both of yield per K.W.H., and concentration of nitric oxide in the arc gases, the technical nitrogen fixation arc processes are capable of considerable improvement.

The essential distinguishing features of the various nitrogen fixation arc processes in successful operation to-day lie chiefly in the nature of the arc

furnaces employed. There are six such different types of furnace, namely the Birkeland-Eyde, Pauling, Schönherr, Moscicki, Guye and Wielogaski furnaces. Only the three types first mentioned will be discussed here ; the others are of lesser importance technically. The Moscicki furnace embodies in the main a combination of the principles underlying the Birkeland-Eyde and Pauling furnaces, the Guye furnace those underlying the Pauling and Schönherr furnaces. All these furnaces make use of high tension arcs in which the ratio of rate of dissipation of energy to volume of furnace is exceedingly high. The short low tension arc, in which the charged particles in the arc stream consist mainly of the electrode vapours, cannot be employed. It would not be possible to pass air at a sufficient rate through such an arc, and the high concentration of electrode vapours would accelerate the decomposition of any nitric oxide formed and result in a poor yield. The unsuitability of the short low tension discharge for nitrogen fixation purposes has nothing to do with the potential gradient of its arc-stream, which is, as has been previously pointed out, of the same order as that of the high tension arc.

THE BIRKELAND-EYDE FURNACE.

Two Norwegians, Christian Birkeland and Samuel Eyde, were the first to achieve success in the design of a high tension arc furnace suitable for the direct oxidation of atmospheric nitrogen. Making use of the then already well known fact that an arc could be deflected and quenched by a magnetic field, they burned a high tension alternating current arc between two electrodes so situated between the poles of a powerful electromagnet that the field of the latter was at right angles to the shortest line bridging the electrode gap. On striking, the arc at first follows this line, but, behaving like a flexible conductor, it is deflected and bowed out in such a manner as to sweep out a plane at right angles to the magnetic field, the direction of deflection depending upon the direction of current flow in the arc and the polarity of the poles of the electromagnet. Not only is the arc-stream deflected, but its origins are also forced away from the points of the electrodes. If the magnetic field be sufficiently intense, the arc will be bowed out to such an extent that its apparent resistance eventually equals that of the electrode gap. The moment this occurs, the gap will once more be bridged by the striking of a fresh arc, and the ensuing drop in the potential difference of the electrodes will result in the first distended arc being extinguished. In the Birkeland-Eyde furnace, the coils of the electromagnet are supplied with direct current, and the arc with alternating current. During successive half cycles, the arcs on striking are bowed out first on the one then on the other side of the electrodes. This quenching process is repeated so rapidly (with a periodicity of 50), that the general appearance presented by a succession of these arcs is that of a thin, flat, almost circular disc of flame (Fig. 26). If the magnetic field be weak, the area swept out by the flame will be small, and the load fluctuations excessive, thus rendering impracticable a high

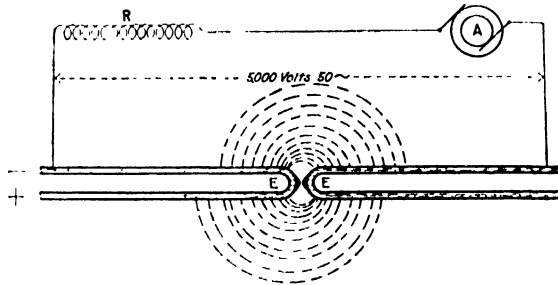


FIG. 26.

rate of dissipation of energy. If, on the other hand, the field is too powerful, then a succession of arcs will be formed during each half cycle, resulting in a lowering of the power factor of the arc and repeatedly renewed and hence useless contact of the discharge with already arced gases. When correctly adjusted the strength of the magnetic field is such that only one arc is formed at each half cycle. Included in the arc circuit is a series inductance, the function of which is to improve the power factor of, and to steady the discharge. Fig. 27 is a sec-

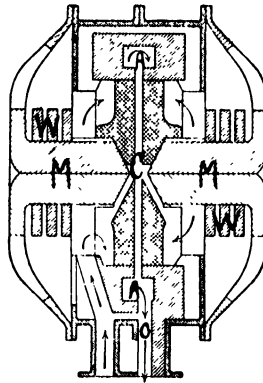


FIG. 27.

tional elevation at right angles to the electrodes of the latest type of the Birke-land-Eyde furnace. MM are the poles of the drum-shaped electromagnet, which completely encloses and forms the outer casing of the furnace, and WW are the pole windings. The furnace is lined with fire brick with suitable perforations through which air is drawn into the shallow arc chamber, C, the diameter of which is about 3 metres. A is a ring shaped duct surrounding the arc chamber and serving to collect the arced gases which leave the furnaces through the exhaust main, O. The flow of the gases is indicated by arrows, and it will be noticed that it is in such a direction as materially to assist in quenching the arc. The electrodes consist of two water-cooled copper tubes bent into narrow horse shoe shape, the two bends being so close to each other (about 1 cm. apart), that the voltage supplied to the electrodes exceeds the striking potential of the

arc. Alternating current of a periodicity of 50 is supplied at approximately 5,000 volts. Units of the type illustrated are built up to 5,000 K.W. capacity. The arc power factor varies from 0.8 to unity, but the over-all (arc and series inductances) power factor is lower, varying from 0.65 to 0.8, according to the size of the furnace. About 1 per cent. of the energy supplied is consumed by the electromagnet. Much of the air passing through the furnace is "false," *i.e.*, it does not come into actual contact with the arc. Such false air, however, serves two useful purposes, namely, (i) it prevents excessive heating of the refractory lining and (ii) it mixes with the arced gases and chills them down rapidly to a temperature (about 1,000° C.), at which the decomposition of nitric oxide is exceedingly sluggish. Thus the gases leave the furnace at about 900 to 1,000° C., and contain approximately 1.3 per cent. of nitric oxide. The yield reckoned as nitric acid is about 65 grams K.W.H. Thus the process efficiency is about 2.6 per cent. From the above data it can be calculated that the average furnace efficiency is about 66 per cent.

THE PAULING FURNACE.

Quenching of a high tension arc by means of a powerful air blast is the essential feature of the furnace invented by the brothers Pauling. The electrodes are

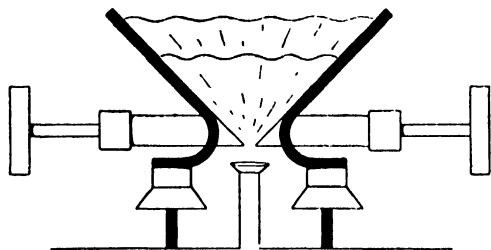


FIG. 28.

horn-shaped and resemble lightning arresters (Fig. 28). Narrow, knife-shaped "kindling blades" pass through the horizontal arms of the electrodes, both of which can be adjusted towards each other from outside the furnace. The main electrodes are water-cooled and, in the original furnace, were made of iron. It was found, however, that iron dust torn off from the electrodes and mingling with the furnace gases led to poor yields due to catalytic decomposition of nitric oxide. A more satisfactory electrode material, consisting of an alloy of aluminium with small quantities of barium and lead, was later introduced by Rossi. The life of the Rossi electrodes, however, is short and replacements are necessary at three day intervals. The degree of separation of these main electrodes is such that the supply voltage is insufficient to strike the arc. The kindling blades serve to decrease the effective gap between the electrodes in order to enable the arc to be struck, but at the same time, being thin and knife-shaped, they do not interfere with the air blast entering the furnace through the

tuyère. When the air blast impinges upon the arc formed between the kindling blades, the sequence of events is much the same as that occurring in the Birke-land-Eyde arc. The arc is distended and blown upwards, the arc stream origins leaving the kindling blades and travelling up the horns of the electrodes. When, owing to this distortion, the potential drop across the distended arc exceeds the normal striking voltage, a fresh arc starts between the kindling blades. With a 50-cycle current supply, this process occurs so rapidly that the discharge resembles a large, flat flame rising up from the horns of the electrodes

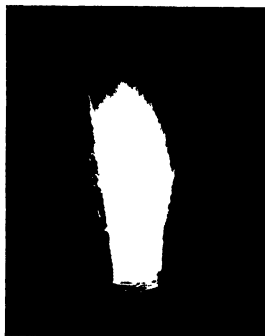


FIG. 29.

(Fig. 29). The Pauling furnace contains two such arcs in series, each situated in separate chambers (see Figs. 30 and 31, shewing front and side elevations respectively). Previously arced, but cooled gases are blown in through the

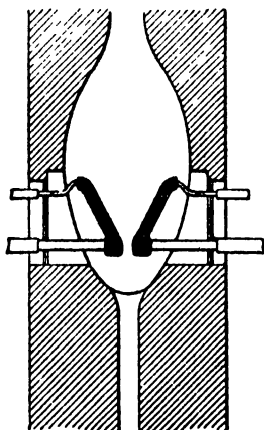


FIG. 30.

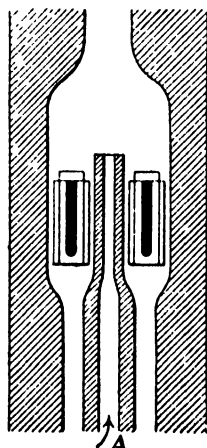


FIG. 31.

tuyère, A, and mingle with the hot arced gases in the main furnace chamber above the arcs. The overall power factor (5,000 volts ; 50 cycles), is 0.6 to 0.7. The gases contain only 0.8 per cent. nitric oxide, but the yield with Rossi electrodes may reach the high value of 75 grams of nitric acid K.W.H. The

furnace consumption is about 600 to 700 K.W. (300-350 K.W. per arc). Larger units have not proved satisfactory in practice.

THE SCHÖNHERR-HESSBERGER FURNACE.

The development of this furnace is due to Schönherr and Hessberger of the Badische Anilin und Soda Fabrik. In principle it is totally different from the Birkeland-Eyde and Pauling furnaces. In these the arc is quenched, i.e., immediately after striking, the arc is lengthened and finally quickly extinguished by what virtually amounts to a rapid widening of the effective separation of the electrodes, the process being repeated at least once during each half cycle. In the Schönherr furnace, the arc, on striking across the narrow gap between the electrodes, is also immediately distended, but a halt is called in such virtual widening of the electrode gap before rupture of the discharge occurs. By means of a suitable current of air enclosing spiral-wise the path of the arc, the hot ionised gases of the arc-stream are sufficiently preserved *in situ* during the reversal of the current at each half cycle to enable the fresh arc to start up at once in the track of the preceding arc. In the main, the Schönherr furnace (Fig. 32), consists of a long vertical iron tube which serves as one of the electrodes until the arc is fully extended and its upper end lodges on the water-cooled iron plug, F. A small insulated water-cooled iron rod situated in line with the axis and at the lower end of the tube acts as the other electrode. To start the arc the gap between these electrodes is decreased by means of an electromagnetically or hand-operated plunger pin. Air is blown in at the bottom of the furnace through jets opening tangentially into the main tube. A whirling helical motion is thus imparted to the air which carries the one origin of the arc up the main tube to the upper electrode. The air column through which the arc passes in the centre of the main tube flows slowly and is neither agitated nor cooled to any great extent by interchange with the cool swirling air which surrounds it.

Thus a sufficiently highly ionised column of gas is left at the close of each half cycle to enable a fresh arc to restrike at a comparatively low voltage along the track of the previous one. The resulting stable arc may attain a length of 30 ft. or more. These furnaces have been built and operated to take up to 1000 K.W., at a voltage of 3,500 volts. The overall power factor is about 0.7, that of the arc alone approaching unity.

While the general efficiency of the Schönherr furnace is much the same as that of either the Birkeland-Eyde or Pauling furnaces, the nitric oxide concentration is considerably higher, averaging as much as 1.8 per cent. That this is so, in spite of the fact that the gases only pass slowly along and through the arc, is strong evidence to the effect that the oxidation of nitrogen in the high tension arc is primarily an electrical process.

Of the relative advantages of the three types of nitrogen fixation arc furnaces described above, there is little to be said. They have in common, simplicity, absence of moving parts and robustness. From the point of view of efficiency

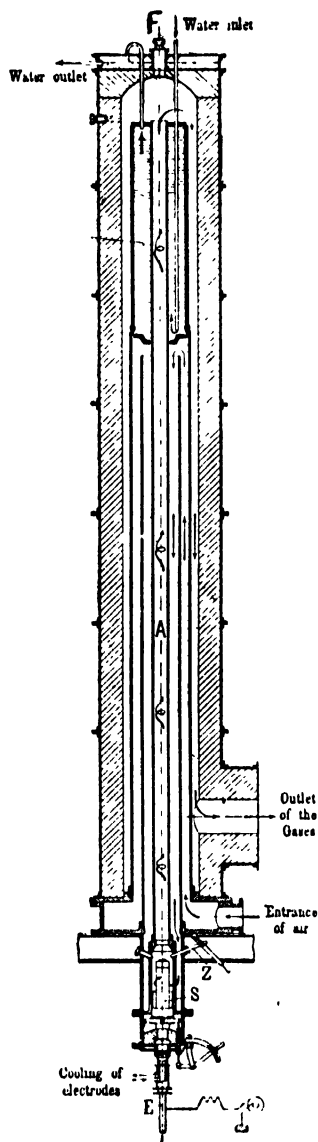


FIG. 32.

they also stand on much the same level, though the Schönherr furnace undoubtedly yields the richest gas. From the point of view of first cost, the Pauling furnace is the cheapest, the Birkeland-Eyde the most expensive. On the whole, however, the latter seems to be the most successful. This is doubtless due to the fact that single Birkeland-Eyde units can be built to take and be operated successfully under the enormous load of 6,000 K.W., whereas the practical upper load limit of the Schönherr furnace is about 1,000 k.w., and somewhat lower in the case of the twin series arcs Pauling furnace.

NOTES ON BOOKS.

ON LEAVING SCHOOL AND THE CHOICE OF A CAREER. -By Sir Charles Cheers Wakefield, Bart. London: Hodder and Stoughton, 1927. 3s. 6d.

This book should prove of very great value to the large number of youths who leave school each term, and perhaps still more to the parents who are planning their future in life.

The author, as one of our modern captains of industry as well as an Alderman and former Lord Mayor of the City of London, is eminently qualified to act as mentor to the youth of this country and to address them on the choice of a vocation. His remarks on character and the need for self-reliance are uncommonly shrewd and should be studied by all. Sir Charles Wakefield deals at length with the necessity for an adequate training for commercial life and insists that a fluent and intelligent command of English in speech and writing is one of the main essentials. Two chapters are devoted to a detailed survey of the public services and the various professions, as well as of the many branches of commerce which afford openings to boys just leaving school; another chapter describes similar opportunities for girls.

The work covers a wide field and contains many practical hints of value--the fruit of the author's experience and observation as a practical business man. The fact that a second edition of this book has already been called for proves that its success is assured.

SMALL MANOR HOUSES AND FARMSTEADS IN FRANCE. By H. D. Eberlein and R. W. Ramsdell. With introduction by Leigh French, Jr. J. B. Lippincott Company, Philadelphia and London.

The subject of this rather sumptuous book is a most inviting one, especially to those who periodically regret the quieter civilization of pre-industrial Europe. The typographer may find the title page, with its caligraphic lettering, unsatisfactory; and the type used in the body of the work is unpleasantly dazzling, for the familiar reason that the upstrokes are too thin in relation to the downstrokes.

Once the mawkish opening of the book has been negotiated, or skipped, many interesting observations await the reader. The authors, who are evidently American, feel it necessary to justify the labour they have expended on such an exotic subject as old French houses by insisting that American styles of architecture are eclectic, and that there may consequently still be something to learn from the decaying manors of an old continent. But after these apologies from Mr. Leigh French, Junior, and some rather patronising stuff from either Mr. Eberlein or Mr. Ramsdell or both, we get down to hard tacks. Their knowledge is vastly superior to their command of English. What can be the sense of writing such sentences as the following? "As most French people generally can, when they have a mind to, the makers and keepers of the old gardens, however, not seldom made a virtue of necessity, or, to put it a little differently, they very often contrived to clothe the necessity with grace, cabbages and turnips representing necessity, and roses and lilies standing for grace."

However, interesting studies are given of French garden-planning and furniture-making, as well as manorial architecture. The authors have remarked a very significant trait of the French national character when they point out what they describe, with incurable pomposity, as "the intimacy of relationship in utilitarian functions existing between the master's dwelling and all the other buildings that represent the various farm and estate operations." In other words, the French country gentleman did not feel it incumbent on him to hide his chicken-runs and

pig-sties away out of sight of his house. Sometimes the stables and the private chapel adjoined. This is why certain congregations carried with them an unmistakable horsey smell, and not because, as the priest would have it, "our Lord was born in a stable, and the smell has always stuck to His true people."

Various very attractive houses are described and illustrated. Remarkable are the classical lines of the Manoir Jestin, still more so the plan of its semi-circular coach-house. About the Chateau d'Odre at Maquingen there is a greater, and somehow very French, urbanity; yet both these places fit their rural environment. The farm, Le Grand Moulin, at Isques, would undoubtedly—to use a French idiom—make the happiness of a painter.

Quite what the house of Diane de Poitiers, at Orléans, is doing in this book it would be difficult to explain: with its Corinthian columns and heavily barred windows. But it is so beautiful that its intrusion is not likely to be resented. The *gentilhommière* of Sablon is charming. Exquisitely simple and civilised, it is the very place for an eighteenth century shepherdess to have gone to live in after her marriage to the young squire.

P.B.

HISTORY OF THE JAPANESE COTTON INDUSTRY.

The following particulars have been extracted from a detailed report on the cotton spinning and weaving industry in Japan, written by His Majesty's Consul at Osaka:—

The Japanese cotton industry was established in 1867, the first mills being erected at Kagoshima, in Kyushiu. For many years only a very moderate degree of success was attained, and it was not until 1896, in which year the import duty on raw cotton was abolished, that the industry became one of national importance. By 1899, however, exports had reached a total of thirty million yen, consisting almost entirely of coarse count yarns.

With the gradual advance in the standard of living in Japan and the development of the export trade the Japanese mills first began to turn their attention to a slightly finer range of counts in 1905, and exports in that year amounted to yen 49,000,000 in value, of which yen 16,000,000 represented piece goods. The total production of yarns in that year reached 900,000 bales, out of which a total of 267,000 bales were exported.

It was, however, the European war which accorded to the industry its great opportunity and led to unprecedented development. Not only did Japanese manufacturers find themselves freed from competition in their main market—China—but, owing to the incapacity of England and other regular suppliers to meet the demand, they were enabled to build up a great trade in substitute goods with markets such as India, the Netherlands East Indies, South America, Africa, and other countries to which they had not previously found entry.

After the restoration of peace the Japanese industry suffered, with those of other countries, from the post-war slump of 1920 and 1921, and the export of Japanese cotton goods, both yarns and textiles, to the war-time markets fell off to a marked degree. Exports to pre-war markets, such as China, on the other hand, were fairly well maintained in view of the unfavourable conditions prevailing.

But since 1921, notwithstanding the earthquake disaster in September 1923, the industry has resumed the progress temporarily checked by conditions arising from the ending of the war. In 1925, production, both of yarns and textiles, attained record figures, which, considering the difficulties which still beset the

world's cotton industry, must be regarded as a real achievement. In this connection it should be remarked that, with the exception of the silk industry, the cotton-spinning and weaving industry is the only one of Japan's industries which has, on the whole, emerged unweakened from the post-war period, a fact which may be ascribed to three causes, namely, the natural suitability of the country for an extension of the industry, the excellent manner in which the industry is organised and managed, and the strong foundations established in the course of the past quarter of a century. The following figures afford a general idea of the growth of the spinning and weaving industry since 1903 :—

No. of mills " " spindles	1903	1913	1925
	—	152	230
ring	1,295,000	2,365,000	5,152,000
mule	86,000	49,000	34,000
doubling spindles	127,000	321,000	752,000
looms	5,043	24,224	68,160

The above figures only include companies which are members of the Japan Cotton Spinners' Association, which, however, controls at least 90 per cent. of the total spindleage of the country and between 40 and 50 per cent. of the power looms utilised for cloth of greater width than the standard Japanese width of 15 inches. Full particulars relating to spinning companies not affiliated to the Association are not available.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, OCTOBER 10. Automobile Engineers, Institution of, at the Merchant Venturers' Technical College, Bristol. 6.45 p.m. Major E. G. Beaumont, "The Influence of the Automobile User upon the Automobile Engineer."

Brewing, Institute of, at Engineers' Club, 39, Coventry Street, W. 7.45 p.m. Messrs. S. Harold Thompson, A. C. Reavenall, and H. Heron.

Metals, Institute of, at 30, Elmbank Crescent, Glasgow. 7.30 p.m. Mr. S. E. Flack, Chairman's Address.

Transport Institute of, at the Institution of Electrical Engineers, Victoria Embankment, W.C. 5.30 p.m. Mr. Roger T. Smith, "Main Line Railway Electrification."

University of London, at University College, Gower Street, W.C. 5 p.m. Mr. R. J. Lythgoe, "Vision." (Lecture I.)

TUESDAY, OCTOBER 11. Academy of Arts, Royal, Burlington House, W. 4.30 p.m. Prof. Dr. Arthur Thomson, "Anatomy—The Bones and Muscles of the Trunk, and the Surface Forms dependent thereon, in Action and Repose.—Part II."

Heating and Ventilating Engineers, Institution of, at Caxton Hall, Westminster, S.W. 7 p.m. Dr. J. S. Owens, "Atmospheric Pollution."

Marine Engineers, Institute of, 85-88, The Minories, E. 6.30 p.m. Mr. A. F. C. Timpson, "A New Form of Insulating Material for High Temperatures."

Philosophical Studies, British Institute of, at the Royal Society of Arts, Adelphi, W.C. 8.15 p.m. Drs. John Rickman and H. G. Baynes, "The Standpoints of Freud and Jung."

Quekett Microscopical Club, 11, Chandos Street, W. 7.30 p.m. Dr. W. B. Brierley, "The Microflora of the Soil."

Wireless Technology, Institute of, at the Engineers' Club, Coventry Street, W. 7 p.m. Mr. G. Leale Norrow, "The Design of a Resistance-Capacity Amplifier for Broadcast Reproduction."

University of London, at the Institution of Civil Engineers, Great George Street, Westminster, S.W. 5.30 p.m. Prof. Dr. Adolf Nagel, "Heat Transfer in Reciprocating Engines, including Internal Combustion Engines." (Lecture I.)

WEDNESDAY, OCTOBER 12. Egypt Exploration Society, at the Royal Society, Burlington House, W. 8.30 p.m. Dr. H. R. Hall, "Tuthmosis III." (Lantern slides). Metals, Institute of, at Thomas' Café, High Street, Swansea. 7 p.m. Captain L. Tavernier, Chairman's Address.

Public Health, Royal Institute of, 37, Russell Square, W.C. 4 p.m. Dr. C. W. Saleeby, "Sunlight for Childhood."

University of London, at University College, Gower Street, W.C. 5 p.m. Mr. R. J. Lythgoe, "Vision." (Lecture II.)

THURSDAY, OCTOBER 13. China Society, at the School of Oriental Studies, Finsbury Circus, E.C. 5 p.m. Professor A. von Lecoq, "Central Asia: The great transmitter of Western culture elements to China, and of Chinese culture elements to the West."

Mechanical Engineers, Institution of, at the Hotel Metropole, Leeds. 7.30 p.m. Mr. W. H. Atherton, "Modern Conveying Machinery."

Metals Institute of, at 83, Pall Mall, S.W. 7.30 p.m. Mr. A. H. Munday, Chairman's Address, "Works Economics."

FRIDAY, OCTOBER 14. Academy of Arts, Royal, Burlington House, W. 4.30 p.m. Prof. Dr. Arthur Thomson, "Anatomy—The Bones and Muscles of the Trunk, and the Surface Forms dependent thereon, in Action and Repose.—Part III."

Engineering Inspection, Institution of, at the Royal Society of Arts, Adelphi, W.C. 7.30 p.m. Mr. C. M. Read, "Electric Power Cables and Recent Developments."

Metals, Institute of, at the Applied Science Department, University of Sheffield. 7.30 p.m. Mr. J. H. G. Monypenny, Chairman's Address, "Science and Industry."

University of London, at University College, Gower Street, W.C. 5 p.m. Mrs. P. M. T. Kerridge, "Hydrogen Ion Concentration." (Lecture I.)

University of London, at the Institution of Civil Engineers, Great George Street, Westminster, S.W. 5.30 p.m. Prof. Dr. Adolf Nagel, "Heat Transfer in Reciprocating Engines, including Internal Combustion Engines." (Lecture II.)

SATURDAY OCTOBER 15. Horniman Museum, Forest Hill, S.E. 3.30 p.m. Miss M. A. Murray, "Egyptian Temples."

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All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2.)

NOTICE.

OPENING OF THE 174th SESSION.

The Opening Meeting of the 174th Session will be held at 8 p.m. on Wednesday, November 2nd, when the Inaugural Address will be delivered by SIR PHILIP MAGNUS, Bt., Chairman of the Council. The subject will be "The Royal Society of Arts : its Services to Trade and Training."

After the delivery of the Address, the Society's silver medals awarded for papers read last session will be presented.

PROCEEDINGS OF THE SOCIETY.

CANTOR LECTURES.

SOME INDUSTRIAL APPLICATIONS OF ELECTROTHERMICS.

By G. I. FINCH, M.B.E.,

Assistant Professor of Electrochemistry, Imperial College of Science and Technology.

LECTURE III.—ELECTROTHERMICS AND METALLURGY.

(Delivered March 28th, 1927.)

INTRODUCTION.

During the last twenty years the electrothermic production of steel has developed into an important and rapidly expanding industry.

Beginning with the crude iron ore, the electrical manufacture of steel may be divided into two stages, namely, (i) the electrothermic smelting of iron ores for pig iron, and (ii) the electrothermic refining of pig iron and low grade

steels to high grade steels. The thermal production of pig iron in the blast furnace is, however, on the whole a comparatively efficient process, approximately 1 ton of coke being sufficient for the production of 1 ton of iron. Of this amount of coke, approximately 6 cwt. is employed in the chemical reduction of the ore and its impurities and for the carbonisation of the iron, and the remaining 14 cwt. serve to supply by their combustion the heat absorbed by the endothermic reaction in which the iron ore is reduced. In the electrothermal production of pig iron, this heat of reaction is supplied electrically. Thus whether or not the electrothermal process can compete with the purely thermal process is largely a question of the relative costs of electricity and fuel. Bibby (*Engin.* 107, 649 (1919)) has calculated that the two processes will be on a par when the cost of 1 K.W. year is equal to that of 3.1 tons of coke, i.e. when 1 Cal. can be generated electrically at a cost equivalent to only 3.3 fuel-produced Cal. It is clear that this will be the case only in countries where fuel is scarce, but electrical power cheap; and these conditions, coupled with readily available supplies of the otherwise necessary raw materials, are not encountered either in this country or in the Dominions, except, possibly, in Canada. At present the electric smelting of iron ore is practically confined to Scandinavia and, to a lesser extent, California. In the former country, where the conditions are most favourable, the electrothermal production of pig iron has advanced rapidly and now ranks as a leading industry. In the case of steel-making, however, the question of relative fuel and electricity costs is, for reasons which will be gone into at a later stage, of far less importance. The electrothermal production of steel, therefore, is now well established as an important industry in most civilised countries.

Electrometallurgy of Steel. Thermally, steel can be made in a variety of ways, the finished product usually being named after the process by which it was produced. Two main groups of methods may be distinguished, according to whether the steel is produced by the refining of impure materials, or by the simple melting together of pure materials. Acid and basic Bessemer or open-hearth processes are examples of the first group; the second includes the crucible and similar melting-up processes by which steel and special alloy steels are produced, without refining, from pure materials. The above steel making methods may be employed singly or in combination according to the degree of purity of the raw materials and the nature of the finished product aimed at. Refining to crucible steel quality of impure materials, particularly of pig iron of high phosphorus contents, cannot, however, be carried out in either the Bessemer or open-hearth processes, and the thermal production of crucible and high-grade alloy steels involves the use of pure high-grade raw materials. In electrothermal steel making, on the other hand, steels of any desired quality can be produced from either pure or impure materials.

The following possible cases of electrothermal steel production can be distinguished:—

A. Melting, non-refining processes :

- (i) Pure materials melted to crucible quality steel.
- (ii) Pure materials melted to high-class alloy steels.
- (iii) Scrap steel and other materials, which, though impure, are yet sufficiently pure for the purpose, are melted to steel of open-hearth quality.

B. Refining processes :

- (i) Pig iron refined to steel of open-hearth or crucible quality.
- (ii) Bessemer steel refined to steel of open-hearth or crucible quality.
- (iii) Open-hearth steel refined to crucible steel.
- (iv) Scrap steel and other materials melted and refined to steel of open-hearth or crucible quality.

In all cases the metal can be charged into the electric steel furnace either cold or molten. The electrothermal refining of pig iron is seldom carried out, the molten pig iron being either first partially refined in the Bessemer converter, or in the open-hearth furnace with an oxidising slag, and then finished in the electric furnace with a basic reducing slag (Duplex process) ; or the molten pig iron is first blown in the Bessemer converter, then further refined in the open-hearth furnace and finally finished in the electric furnace (Triplex process).

In the U.S.A. the electric furnace is widely used in conjunction with the Bessemer converter or the open-hearth furnace, or both, for the production of high-class rail steel and steel for constructional and shipbuilding purposes from pig iron of high phosphorus contents. In that country, indeed, the electric furnace may be deemed to have endowed the Bessemer converter with a new lease of life. In this country the electric steel furnace is employed almost solely in the melting up of high-grade scrap steel, the shape of which is too awkward to permit of the use of the crucible. Refining is not carried out.

The two chief uses to which the electric furnace is put are : (i) to melt pure materials to steel of crucible quality, and (ii) to refine Bessemer or open-hearth steel or scrap steel of similar quality to steel of crucible quality.

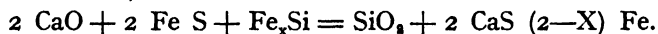
The mechanism of the electrothermal production of steel from pure materials is relatively simple and resembles that of the crucible steel process. Scrap steel of suitably low sulphur and phosphorus contents is melted down in the electric furnace, and the carbon contents are adjusted by additions of pure high carbon iron and pure iron ore, or better, low carbon scrap. After melting, the charge is kept molten in order to enable occluded oxides and gases to escape to the surface. This "killing" operation, which may be hastened by the addition of ferro-silicon and ferro-manganese, is far more readily and thoroughly effected in the electric than in the acid open-hearth furnace owing to the strongly reducing atmosphere and higher temperature of the former. Finally, when alloy steel is being produced, the process is completed by the addition of the

suitable ferro-alloys or alloying elements, after which the metal is ready for teeming. The reducing atmosphere and the high temperature attainable render the electric furnace particularly suitable for the making of alloy steels, as the loss of costly alloying elements is low and it is easy to incorporate in the steel difficult fusible metals such as tungsten. Compared with the crucible process, the electric furnace possesses further important advantages. Operations can be carried out on a far larger scale, comparable with open-hearth treatment, and there is no risk of contamination of the steel with flue gases or the crucible material such as is liable to occur in the crucible process. This tends to greater uniformity of the finished product, together with a reduction of operating costs. The steel is at so high a temperature that it is possible to make intricate castings with a minimum liability to flaws. From the point of view of thermal efficiency, the advantage is overwhelmingly in favour of the electric furnace with its intense and localised heat production. Starting with cold materials, the energy consumption in the electric furnace amounts to about 500 to 600 K.W.H. per ton of finished steel, equivalent to about 430,000 to 516,000 Cals. (electrically produced), as compared with $1\frac{1}{2}$ to 2 tons of coke, equivalent to, say, 12,000,000 to 16,000,000 Cals. (fuel produced) per ton of steel made by the crucible process.

It has been shown previously that in this country the cost of generating electricity is so high that in order to be on the safe side it is necessary to put the cost of 1 Cal. electrically generated at about 18 Cals. produced from fuel. Thus, expressed in terms of fuel-produced heat, the cost of making 1 ton of steel from cold scrap in the electric furnace lies between 7,740,000 and 9,288,000 Cals., as against 12,000,000 to 16,000,000 Cals. required per ton of steel made by the crucible process. It is clear that on economic grounds alone the crucible process is to be considered as wasteful. In the U.S.A. the electric furnace has, to a large extent, superseded the crucible. That it has not done so as yet in this country can be ascribed to a variety of possible reasons, such as, for instance, the present excessive and unjustifiably high cost of electricity and the still persistent belief, long since proved to be without foundation, that electric steel is inferior to crucible steel. The superb skill of the crucible steel maker, acquired in the course of the century and a half which have elapsed since the inception of the industry, is worthy of a better tool than the scientifically unsound crucible. Such an implement is available in the shape of either the high frequency electric furnace for the production of special steels of the highest grades in small batches, or the arc furnace for larger batches of steel of, or even excelling, crucible quality.

The conditions under which impure metallic charges are refined in the electric furnace differ essentially from those met with in the Bessemer converter or open-hearth furnace, in that refining is carried out at a higher temperature and in a strongly reducing atmosphere. The mechanism of electric steel refining, therefore, also differs in several interesting particulars from that of

the directly thermal processes. Should the sulphur and phosphorus contents of the impure metal be below the limits permissible in the class of finished steel aimed at, then an acid lined electric furnace and an acid slag may be used. Ferro-alloys will be added to the slag, not as deoxidisers, but merely for the purpose of adjusting the carbon, silicon and manganese contents of the metal to those required in the final product. The advantages of the acid treatment lie chiefly in the ease and cleanliness with which steel can be handled under an acid slag and also in the fact that a single slag treatment is sufficient. Steel of open-hearth quality may conveniently be produced in this manner from low-sulphur, low-phosphorus scrap. More often, however, the impure metal contains carbon, sulphur and phosphorus in excess as well as silicon and manganese. The electric furnace must, then, have a basic lining, for the removal of phosphorus involves the use of an oxidising basic slag * produced by the addition of iron ore and lime. As soon as most of the carbon and also the silicon and manganese have been oxidised, the phosphorus oxidises to P_2O_5 and passes into the slag, forming calcium phosphate. This oxidising phosphatic slag is now skimmed off the metal. It is not capable of removing the sulphur in the metal, since $CaSO_4$ is readily reducible by metallic iron to CaO and FeS , the latter readily dissolving in the steel. Removal of the phosphatic slag must be as complete as possible; otherwise on reduction, its phosphorus contents will re-enter the metal. The removal of sulphur now involves the use of a reducing and strongly basic slag containing fluorspar and carbon and often ferro-silicon. The high temperature attainable in the electric furnace permits of the use of extremely limey slags (up to 80 per cent. CaO), thus ensuring a rapid and complete removal of the sulphur. Slags of similar basicity could not be employed in the open-hearth furnace owing to their viscosity at the relatively much lower temperatures there prevailing. At first, dissolved oxides are eliminated, after which the formation of CaS , which is insoluble in the steel, commences, thus:



The frequently observed formation of CaC_2 in the electric steel furnace bears witness to the existence of the high temperatures and the reducing atmosphere so essential to the successful carrying out of this second stage of the process. Upon removal of the second slag, the steel is "killed," recarburised and alloyed in the manner previously outlined. The resulting product is, in quality, fully equal, or even superior, to crucible steel, and certainly exceeds the latter in uniformity over large batches.

From the foregoing it is clear that pig iron can be refined in the electric furnace to a steel of the highest quality. On economic grounds, however, this is seldom done. The usual procedure is to carry out a preliminary refining of the pig iron in the open-hearth furnace, or at least in the Bessemer converter,

* For instance, approximately 40 per cent. CaO , 10 per cent. SiO_2 , 35 per cent. FeO and Fe_2O_3 .

and to complete refining in the electric furnace which is charged not only with the molten open-hearth steel but also with the steel scrap of similar or better quality which inevitably results from steel works operations.

The reasons for this procedure become apparent when one considers the energy consumption involved in the production of steel. The refining of molten pig iron, to which has been added the necessary quantity of cold iron ore, to open-hearth steel in the electric furnace calls for an expenditure of about 200 K.W.H. per ton of steel. The further refining of this molten open hearth quality steel to crucible steel requires only about 80 K.W.H. In the open-hearth furnace a ton of steel is produced with an average expenditure of about 6 cwt. of fuel or, say, about 450,000 fuel produced Cals., as against, say, $200 \times 860 = 172,000$ electrically produced Cals.

We may now consider some of the characteristic types of electric furnaces in which are carried out the operations outlined above.

Electric steel furnaces may be divided into three classes, i.e. arc, combined arc-resistance, and resistance furnaces.

ARC AND COMBINED ARC-RESISTANCE FURNACES.

In general the electric arc steel furnace consists of a steel shell approaching cubical or spherical shape, lined with refractory material and provided with suitable apertures for charging, tapping and for the admission of the electrodes. The furnace is mounted on trunnions or rocker-castings in such a manner that it may be mechanically tilted about a horizontal axis which may pass either through or nearly through the centre of gravity, in the case of large furnaces, or through the tip of the tapping spout in the case of many smaller types of furnaces. The tilting mechanism is actuated either hydraulically or by electrically driven gearing. The charging doors and electrodes are likewise actuated mechanically, the former by hydraulic rams or electrically, the latter by special electric gearing which, during a run, effects an automatic control of the position of the electrodes and hence, within certain limits, of the power consumption in the furnace.

Four distinct types of Arc furnaces can be distinguished, namely : (i) indirect arc, (ii) direct arc, series arcs, (iii) direct arc with free hearth electrode, and (iv) direct arc with buried hearth electrode (combined arc-resistance) furnaces (Fig. 33).

In the indirect arc type of furnace the metal charge contained in the furnace well or hearth is heated by radiation from the arc maintained between carbon (or graphite) electrodes.

In the direct arc types, the current enters the furnace through one carbon electrode between which and the metal an arc is formed. The current then flows through the metal either (i) to another point on the surface of the bath contents, whence it emerges to form a second arc in series with the first, finally passing out of the furnace through a second carbon electrode (direct arc,

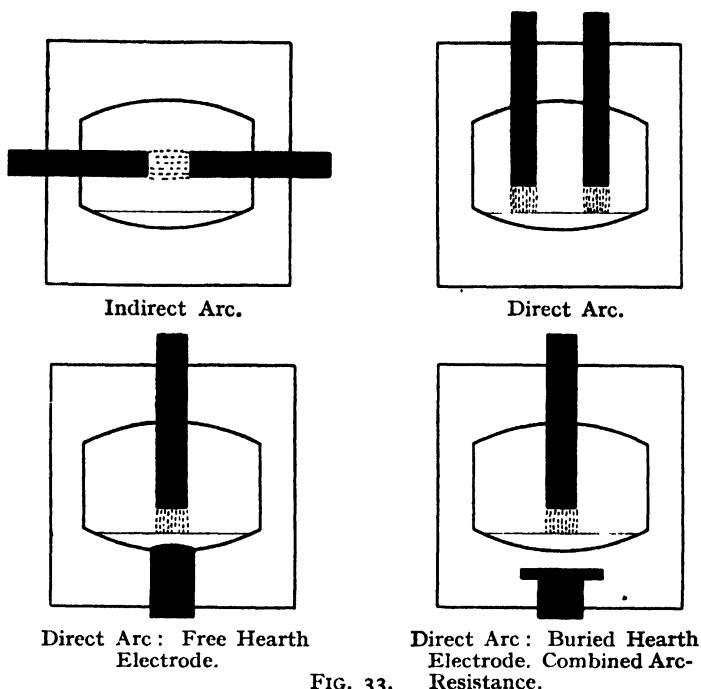


FIG. 33.

series arcs furnace), or (ii) to a solid steel electrode submerged in, and thus in direct contact with, the metal (direct arc furnace with free hearth electrode), or (iii) to an electrode embedded in the hearth but separated from the metal by a layer of refractory material which, being at or near the temperature of the bath contents, is sufficiently conducting to pass the requisite current (direct arc furnace, with buried hearth electrode). Thus, in the case of direct arc furnaces, the bath contents themselves serve as one of the electrodes of the arc or arcs. The metal is heated partly by radiation from the arc and the arc origin on the carbon electrode end, and partly by actual bombardment of the metal surface by charged particles from the arc stream. Again, in the last-mentioned type of furnace (buried hearth electrode) the metal is also heated to a greater or lesser extent from below by the heat developed by the passage of the current through the refractory layer interposed between the hearth contents and the buried electrode. The conductivity of molten steel is such that, in view of the large cross-section of the hearth contents, the quantity of heat generated by the flow of current through the metal may be considered as negligible.

Although steel making in the electric furnace was first developed and carried out successfully on a large scale in France, Italy and in the U.S.A., it is, nevertheless, worthy of note that it was in this country that Sir William Siemens and, independently, Ferranti, invented and demonstrated electric steel furnaces; these inventors may therefore justly claim to be the pioneers of the vast and

important industry into which electric steel making has since developed. Siemens, in 1882, melted steel in a small crucible furnace in which the principles of both direct and indirect arc heating were utilised and first established (Figs. 34 and 35); and Ferranti, in 1887, demonstrated the possibility of

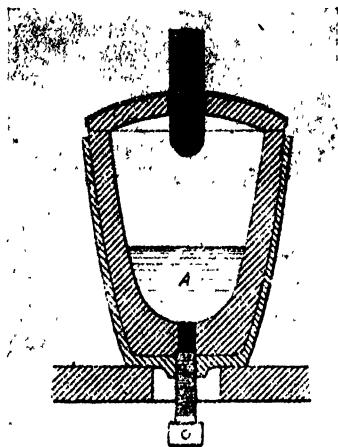


FIG. 34.

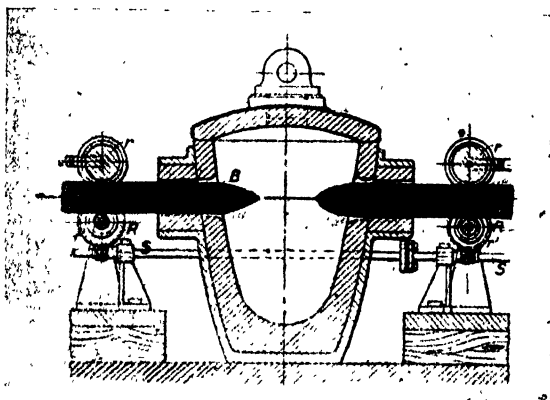


FIG. 35.

melting metals by the heating effect of low voltage currents induced in the metal itself. Ferranti's furnace was the forerunner of the induction type of furnace, of which the Kjellin furnace is such a well-known example. Both Siemens and Ferranti, however, were generally ahead of their times; the dynamo having not yet been brought to the necessary pitch of perfection.

INDIRECT ARC FURNACES.

The earliest successful steel furnace of this type is that invented by Stassano. It consists of a dolomite-lined, cylindrical, flat-bottomed steel shell with a domed roof lined with magnesite brick. Between the inner dolomite layer and the outer shell of the furnace there is a thick lining of refractory material of low conductivity.

The electrodes enter the furnace a short distance above the hearth and are disposed symmetrically round the furnace. They are two in number, when the current supply is single-phase, or three, connected delta-wise in the case of a three-phase supply, the latter being the more usual practice. The electrodes are inclined downwards towards the bath contents in such a manner that the arcs between the electrodes play within a few inches of the surface of the metal. The furnace as described above has three outstanding disadvantages in that (i) the metal is not agitated or stirred, (ii) the refractory lining of the furnace, particularly that of the roof, is fully exposed to radiation from the arc, and finally (iii) the temperature of the hottest portion of the bath contents immediately under the arc is but little above the average temperature of the metal.

Stassano remedied the first fault by mounting the furnace at a tilt and rotating it about an axis inclined from the vertical, thus ensuring satisfactory stirring and mixing of the metal (Fig. 36). Wear and tear of the roof is also reduced by lengthening the cylindrical section of the furnace and thereby increasing the distance between arc and roof—a remedy which, however, involves an increase in the ratio $\frac{\text{outside surface of furnace}}{\text{volume of furnace}}$ and thus lowers the thermal

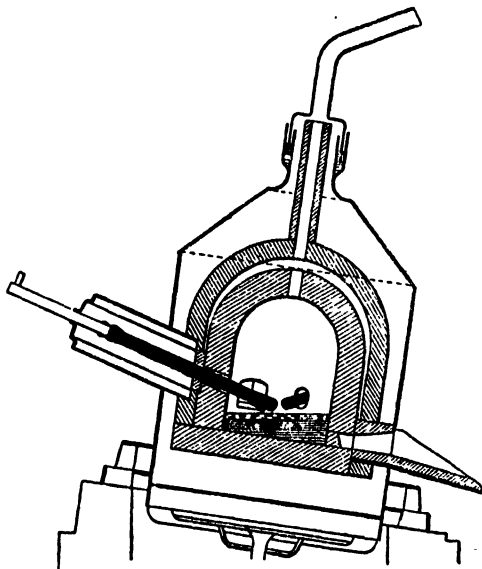


FIG. 36.

efficiency. In the Rennerfelt furnace this defect is avoided, and radiation towards the roof and walls of the furnace is minimised by a more suitable disposition of the three electrodes. Two of these pass through the sides, the third entering the furnace vertically through the roof (Fig. 37). Two-phase current, obtained by Scott connections from a three-phase supply, is employed, the vertical electrode, which is somewhat larger than the side electrode, taking the return current from both phases. As a result of this arrangement, the arc is magnetically deflected downwards towards the bath, and plays over and partly in contact with the layer of slag covering the metal. The arc can be raised or lowered and thus made to follow the level of the contents of the bath, by tilting the side electrodes and raising or lowering the vertical electrode. The latter shields the roof from direct radiation from the arc and from the hottest portion of the bath contents immediately under it, and the downward magnetic deflection and spreading of the arc over the bath contents also greatly reduces the exposure of the side walls of the furnace to direct radiation from the arc. The Rennerfelt furnace is not only employed for steel-making, but also

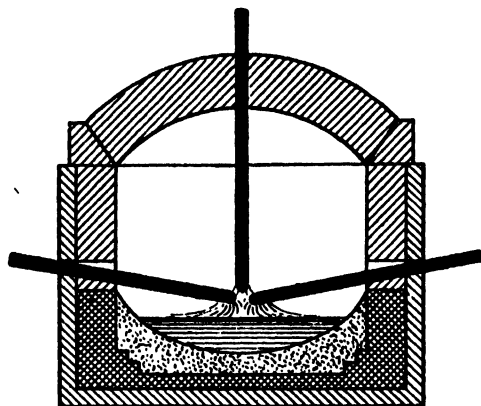


FIG. 37.

in the melting of the non-ferrous metals and alloys, the fairly even heating of the metal enabling even alloys such as brasses containing volatile constituents to be melted without undue volatilisation losses.

Another interesting furnace of this class is the Booth rotating furnace, which is in fairly extensive use in the U.S.A. for the melting of both steel scrap and non-ferrous metals. This furnace consists of a horizontally disposed cylindrical drum supported at either end by two insulated steel rings resting on two pairs of rolls, by means of which the furnace can be rotated about its axis (Fig. 38).

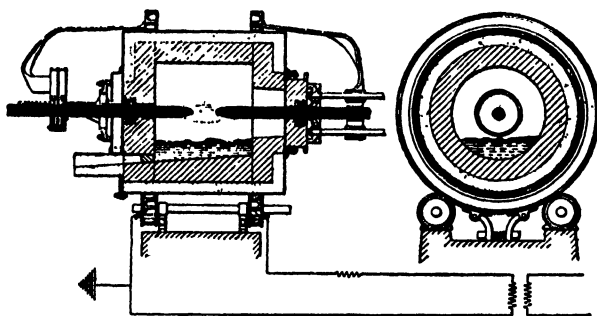


FIG. 38.

The electrodes are located axially, and are thus limited to two in number. The furnace is therefore restricted to the use of single-phase current—which is a drawback. The advantages gained by being able to rotate the furnace are in the main twofold: (i) excessive heating of the furnace lining is prevented, as the exposed sections are continually being submerged in the bath contents, and (ii) extremely thorough mixing of the metal is ensured, a very important consideration in the case of some alloys, such as bronzes, containing lead.

The chief advantages which the above furnaces of the independent arc class have over the other types of arc furnaces which will be discussed later, lie

in the fact that since the arc is maintained between carbon (or graphite) electrodes, and is independent of, and out of contact with, the charge itself, the load is steady and independent of the nature of the charge. Thus charges of a voluminous nature, such as borings and turnings, can be smoothly melted down without any of the violent load fluctuations which occur when scrap steel is melted down in a direct arc furnace, where the charge acts as one of the arc electrodes. This enables the power factor of the installation to be maintained throughout at a very high figure, usually well above 0.9, without undue risk to the electrical supply system. Independent arc furnaces are usually constructed in comparatively small units, seldom exceeding a capacity of 5 tons.

Electrode consumption varies largely according to the nature and duration of the operations carried out in the steel furnace. An average figure when refining open-hearth steel, charged molten, is about 15 to 20 kg. with carbon, and 5 to 6 kg. with graphite electrodes per ton of steel produced. Starting with a cold scrap charge of a similar nature, the consumption of carbon electrode may amount to as much as 30 kg. ton of steel. Much depends also upon the tightness or otherwise of the furnace. Badly-fitting doors and, above all, excessive play between roof electrodes and the water-cooled ports through which they enter the furnace will give rise to air draughts which will flow through the furnace and materially increase electrode consumption through oxidation, besides lowering the valuable reducing properties of the furnace atmosphere.

DIRECT ARC FURNACES.

All furnaces of this class have in common the feature that the hearth contents themselves serve as one of the origins of the arc or arcs maintained in the furnace. Three types of direct arc furnaces may be distinguished, i.e. direct arc furnaces, (i) with series arcs, (ii) with free hearth electrode, and (iii) with buried hearth electrode.

DIRECT ARC-SERIES ARCS FURNACES.

At the end of the last century over-production brought disaster upon the calcium carbide industry, leaving idle a number of water-power stations in Southern France, for which some new application of electric power was urgently needed. It was then that the late Dr. Paul Héroult, who had previously contributed largely to the successful laying of the technical foundation of the modern aluminium industry, turned his attention to the electro-thermal refining of pig iron and converter and open-hearth steels. As a result of his investigations, there sprang up, phoenix-like, out of the ashes of the carbide industry, the new industry of electro-steel, and the electric furnace invented by Héroult (Fig. 39) is not only the most important representative of the direct arc-series arcs class of furnace, but is also to-day by far the most widely used electric furnace for the melting and refining of steel. In the earlier types

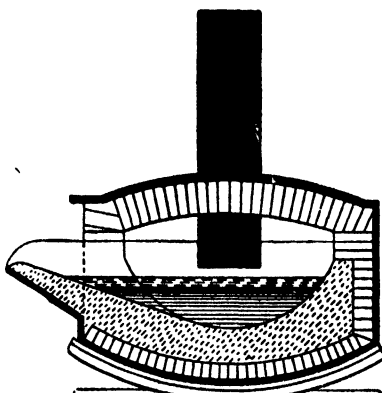


FIG. 39.

of Héroult furnaces, two vertical carbon electrodes entered the furnace through the roof and were supplied with single phase current, the arcs forming between the electrodes and the surface of the charge being thus in series. The more recent types employ, however, three electrodes fed from a three-phase supply in which both sets of transformer windings are delta-connected. The outstanding feature of the Héroult furnace is its simplicity and robustness; and in all electrothermic operations, simplicity and ability of apparatus to stand hard knocks lies at the root of success. These furnaces have been built up to 40 tons capacity. In the most recent installations, Söderberg electrodes are employed. The power factor is high; about 0.8 to 0.85 when melting down, and as much as 0.94 with the charge molten.

DIRECT ARC, FREE HEARTH ELECTRODE FURNACES.

The best-known representative of this class is the Girod furnace (Fig. 40). In its essential features it was anticipated by Sir William Siemen's direct arc furnace. Current enters through one or more vertical electrodes passing through the roof and flows thence by means of an arc or arcs in parallel to

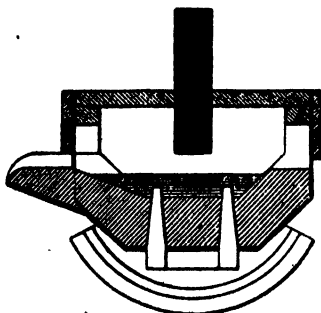


FIG. 40.

the bath contents which are in direct contact with a number of water-cooled steel electrodes piercing the hearth, and through which the current finally leaves the furnace. There is therefore only one arc, or a number of arcs in parallel, corresponding to the number of roof electrodes ; the voltage employed is thus only approximately half that of the Héroult furnace, where the arcs are in series. The chief advantages claimed for the Girod furnace are that (i) it is more suitable than the series arc type of furnace for melting scrap because a large current flows evenly from the electrode through the scrap, thus heating and melting the latter by resistance as well as by the arc, and (ii) strong electro-magnetic circulation of the metal is set up. Both claims are undoubtedly well founded ; nevertheless, the second claim may be urged with equal justice in favour of the Héroult furnace which certainly does not suffer from insufficient circulation of the bath contents ; and with regard to the first claim it is quite true that, power for power, the current in the Girod is nearly twice that in the Héroult furnace ; but in practice there appears to be little or no difference between them when it is a case of melting down scrap. If anything, load fluctuations are less in the Héroult than in the Girod furnace. Furthermore, the low voltage, high current supply to the Girod furnace involves more expensive transformers and leads. The smaller sizes of this furnace are single phase, but the larger ones are provided with three roof electrodes and supplied with three-phase current. The primary windings of the furnace transformers are delta-connected, and the secondaries, one of which is reversed, are in star, the furnace shell, to which are connected the hearth electrodes, forming the neutral point. Since one secondary winding is reversed, the flow of current through the bath contents will be, at any one moment, equal to the effective sum of the total currents passing through the electrode, i.e., equal to twice the current in any one roof electrode. The Girod furnace is made in sizes up to 15 tons capacity.

The Snyder furnace is a free hearth electrode furnace, in which the arc is maintained at a considerably higher voltage than the Girod furnace (110 as against about 60 volts), but otherwise resembles the latter, except that it has only one hearth electrode. For the same power, current varies inversely with voltage ; thus, by using a high voltage arc the current is smaller for a given power input, and this results in a saving in the cost of electrical equipment. Furthermore, it has been found in practice that a charge of cold steel scrap may be melted more quickly ; and the reduction of power factor necessary to ensure sufficient steadiness of load when melting down cold scrap of voluminous and irregular shape is less than in the case of a low voltage arc.

The use of a high voltage arc is, however, not without its attendant disadvantages, chief of which is that the furnace walls are far more exposed to radiation from the intensely hot arc origins than in the case of the short low voltage arc where the electrode can more effectively shield the walls. The most important feature of the modern Snyder furnace is its hinged roof, which

can be swung clear of the furnace and thus enables charging to be carried out far more quickly than would be possible through the usual type of door in the side of the furnace. Single phase and two-phase furnaces up to 7 tons capacity, are in operation ; the largest size can be supplied from a three-phase supply.

DIRECT ARC, BURIED HEARTH ELECTRODE FURNACES.

In the free-hearth electrode type of furnace, difficulty may be found in repairing the hearth without burying the hearth electrodes, and the penetration of the hearth by these electrodes undoubtedly increases the risk of leakage of molten steel through the hearth. These disadvantages are obviated in the type of furnace now to be discussed, in which electrical contact is made by means of the refractory lining of the hearth itself. The lining consists, as a rule, of magnesite in one form or another, sometimes mixed with carbonaceous materials, and is practically non-conducting when cold, but when hot becomes a fairly good electrical conductor. When the furnace is cold, no current will pass through the hearth, hence other means must be employed in order to bring the furnace to a temperature at which the hearth will become conducting. The first furnace of this type to be successfully operated was the Electrometals furnace which has been developed chiefly in this country. It has two (or four) vertical electrodes passing through the roof. The hearth consists of a working lining of rammed dolomite, mixed with chrome ore in order to increase conductivity on a layer of dolomite brick. Steel conductors, serving as buried hearth electrodes, are embedded in the lower portion of the hearth, good contact with the dolomite being ensured by a rich mixture of graphite. Two-phase current is supplied to the furnace from a three-phase supply by means of Scott-connected transformers. The hearth electrode acts as a neutral return. With correctly adjusted roof electrodes, a balanced load is obtained only when the resistance of the hearth is negligible. Practically no power, therefore, is expended in the hearth, and there is no particular hearth heating effect. In effect, therefore, the Electrometals furnace functions in much the same manner as a free-hearth electrode furnace.

In the case of the Greaves-Etchell's furnace (Fig. 41), however, the conditions are different. Again, the hearth consists of a dolomite mixture tamped in with pitch on to a copper plate, covered with a rich carbon mixture, at the bottom of the furnace. The current supply is three-phase, two phases being connected to the vertical roof electrodes, the third phase passing to the buried copper plate hearth electrode and to earth. The resistance of the hearth when hot is less than that of the arcs. It is impracticable to make them equal, and in constructing the transformers, special measures must be taken to obtain a balanced load on the high tension delta-connected side of the power supply. The hearth circuit takes about 12 per cent. of the total load. Electrically, the presence of this steady hearth resistance is of the greatest benefit in steadying the arcs and in acting as a buffer in minimising the effects of short

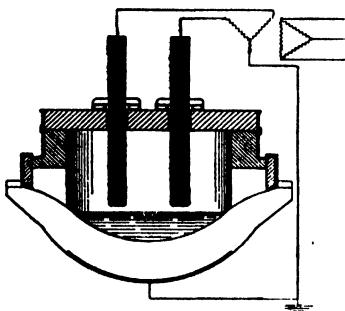


FIG. 41.

circuits during melting. It is therefore possible to cut down the inductance of the furnace circuit to an absolute practical minimum. The power factor of the Greaves-Etchells furnace is accordingly very high, about 0.85 when melting down scrap, but may be made to approach unity during the refining period. These furnaces have been built up to a capacity of 60 tons.

Several of the essential features of the different types and classes of arc furnaces illustrated above may be combined into a single furnace. For instance, the Tagliaferri furnace combines the principles of indirect arc with direct series arc heating. During the melting down period arcs are maintained between the main vertical roof electrodes and auxiliary electrodes which enter, as in the Stassano furnace, through the sides of the furnace. During refining, the auxiliary electrodes are withdrawn, and the discharges then pass between the roof electrodes and the bath contents, the arcs being in series with each other. The furnace is then virtually functioning in the same manner as the Héroult furnace.

Compared with indirect arc furnaces, the chief advantages of the direct arc principle of heating are (i) lessened strain on roof and walls of the furnace, since the roof electrodes to a large extent shield the furnace lining from radiation from the intensely hot arc origins on the ends of the electrodes and on the surface of the bath contents; (ii) far higher local temperatures are attainable; and this fact, whilst rendering direct arc heating unsuitable for melting alloys containing volatile constituents, is of immense advantage in the refining of steel. The exceedingly high local temperatures attained immediately under the electrodes and where the arc strikes the bath contents ensure the setting up of powerful convection currents and permit the use of rapidly acting, efficient and extremely limey slags. In addition to stirring of the metal by convection currents, mixing is also undoubtedly promoted electromagnetically to a considerable extent by the passage of heavy currents through the metal. With regard to the shielding of the furnace walls by the electrodes, this can only be properly effective if the arc origins on the bath contents be vertically below the electrode ends. In view of the fact that the leads supplying the furnace carry high currents of the order of several thousands of amperes, due regard

must be paid to their correct disposition about the furnace, otherwise the arcs are liable to be magnetically deflected and distorted in such a manner that radiation to the furnace walls from the bath contents ends of the arc will be practically unimpeded.

With regard to the relative advantages of the different types of direct arc furnaces among themselves, there is less to be said. Many claims have been put forward in favour of this or that special furnace, but such claims are too often of a frivolous and interested nature. The general opinion of steel makers, expressed in the fact that the Héroult is by far the most widely used of all electric steel furnaces, is overwhelmingly in favour of the Héroult furnace. The Héroult patents lapsed recently, and in consequence one finds several constructors of direct arc, hearth electrode furnaces reverting to the simple series arc principle. The true buried hearth type of furnace, in which a considerable proportion of the power is consumed in the hearth, certainly has the attractive feature of extremely high power factor. Whether the bottom heating effect due to such hearths merits the claims made for it on grounds other than purely electrical is another matter. The fact remains that, in the simple Héroult furnace, no difficulty is experienced in thoroughly heating the metal throughout, and additions of difficult fusible metals, such as tungsten, may be made to alloy smoothly and rapidly with the hearth contents.

RESISTANCE FURNACES.

It has been previously pointed out that the value of the ratio, outside exposed surface of furnace—volume of furnace, should in the interest of economy of heat be as low as possible. Molten steel is an exceedingly good conductor of electricity: but when heating steel by passing an electric current through it, in order to comply with the above conditions the cross sectional area of the steel will have to be made as large as possible. This entails the use of very high currents. Under such circumstances, the use of conductors and electrodes entering the furnace and making contact with the steel is out of the question, owing to the high end losses of heat that would be bound to occur through conduction through the electrodes and leads passing out of the furnace. Such end losses can, however, be entirely obviated if the use of electrodes be dispensed with; and this is feasible if the steel to be heated is contained in an annular hearth surrounding the primary of a transformer, the ring of molten steel thus forming a closed conductor and acting as the secondary. This is the basic principle upon which the only successful types of resistance steel furnace are constructed. Since the currents in the steel are induced, this type of furnace is generally known as the induction steel furnace. The best known representative of this class is the Kjellin induction furnace, now practically obsolete. It consists of two distinct units: the transformer, comprising primary winding and core, and the furnace proper. The core, A (Fig. 42), consisting of laminations of soft iron sheet, insulated

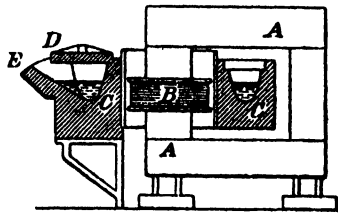


FIG. 42.

from each other to minimise losses, is closed. One arm of the core is surrounded by a primary, B, consisting of a large number of turns of insulated copper wire. In action, the primary and core are cooled by an air blast. Concentric with, and surrounding the primary, is an annular trough of refractory material, the hearth, C, which is provided with a roof, D, of similar material and a tapping spout, E. This is the furnace proper. The whole assembly is rigidly mounted together and provided with means for tilting. In the normal working position, with the hearth lying in a horizontal plane, a charge of molten metal will form a completely closed conducting ring, concentric with and surrounding the primary of the transformer.

A closed liquid conductor, traversed by powerful induced electric currents, exhibits several interesting phenomena. In the first place, the conductor will tend to expand and thus enclose the maximum possible number of lines of force. The resultant effect of this centrifugal force and of the force of gravity is a rolling motion of the hearth contents, the metal rising upwards near the outer side of the hearth and flowing down on the inner side, in the manner indicated by the arrows in Fig. 43. Then the metal also rotates bodily

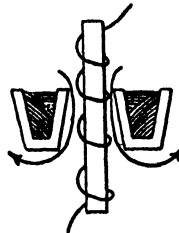


FIG. 43.

round the hearth, an effect which occurs not only in the rotating magnetic field of a three-phase current, but, curiously enough, also in the case of single phase currents. These movements of the metal ensure excellent mixing, but unfortunately, the stirring action is on the whole over vigorous, and results in an all too rapid corrosion of the hearth. This defect is characteristic, not only of the Kjellin, but of all other types of induction steel furnaces.

Another curious phenomenon which is observed when large currents flow through a liquid metal conductor is that known as the "pinch effect," first described by Hering (*Trans. Amer. Electrochem Soc.*, 11, 329 (1907); 15, 255

(1909). A liquid conductor can be regarded as being composed of a number of parallel flexible conductors, all traversed by currents flowing in the same direction. Conductors under such conditions attract each other, and there will thus be a tendency for the metal in the induction furnace hearth to shrink. At one point or another in the metal, where its cross-section is smaller than elsewhere, this shrinking tendency will be at a maximum, since the current density at such a point is also at a maximum. The metal will then tend to recede from either side of the restriction and thus still further decrease the cross-section of the metal and increase the current density at that point; and, eventually, if the current is sufficiently high, rupture of the metal ring will occur and the current will cease to flow. This pinch effect tendency is, however, counteracted by gravity, and the broken ring of metal will again join up and the current restart. The consequences of such a succession of events are serious; at the least, large and sudden load fluctuations occur, and the power to the furnace must be at once cut down. Then with excessively high currents, or slag, or fragments of refractory material unduly restricting the cross-section of the hearth, the pinch effect may become so pronounced that the metal will cool, thus leading to a complete stoppage. In steel, the current density may amount to about 500 amperes per cm.² before trouble is likely to be experienced from the pinch effect, provided the hearth is clean and of suitable shape and dimensions.

It remains to point out some of the advantages and otherwise of the Kjellin furnace. It is clear that the ratio $\frac{\text{outside area}}{\text{volume}}$ is greater than in arc furnaces;

however, in spite of the increase in radiation losses thereby entailed, the Kjellin furnace, thanks to the absence of electrodes, is of all steel furnaces by far the most efficient from the thermal point of view, even when all power losses in the transformer and neighbouring metal masses are taken into account. The atmosphere, however, is necessarily an oxidising one, and the temperature of the metal is throughout uniform. In view of this fact, and of the inconvenient shape of the hearth, the simple induction furnace is of little use for the refining of steel, and really only suitable for melting of scrap or pure materials without improving their quality. Perhaps the greatest disadvantage of the Kjellin furnace, however, lies in its power factor. Owing to the need of keeping the transformer primary and core cool, the metal ring in the hearth is necessarily at a considerable distance from the primary, with the result that only a proportion of the lines of magnetic flux are cut by both metal and primary. Further, the resistance of the metal ring is low compared with its inductance. Both these factors, the former of which can be reduced only by decreasing, the latter by increasing the diameter and cross section of the metal ring, result in a lowering of the power factor. Some improvement is, however, possible by lowering the frequency of the supply current; but such remedy entails the expense of installing special and expensive generators.

A 2-ton Kjellin furnace working off a single-phase 15-cycle supply has a power factor of about 0.6. To attain a similar value with a 4-ton furnace, where the cross section is larger and hence resistance of the metal ring proportionately lower, an 8-cycle supply is necessary.

In the designing of other types of induction furnaces the chief aim has been to improve the power factor. It will be sufficient to consider briefly how this has been effected in the case of the Röchling-Rödenhauser furnace (Fig. 44). Each of the two upright sections of the closed transformer core, A, of this furnace is wound with a primary winding, B; the hearth contents, C, surround each primary in the shape of an "8", the hearth being broadened out into a wide well at the crossover point. On the opposite sides of the well, steel pole plates, E, are let into the walls. The plates are covered with, and separated from, the metal by a layer of the refractory hearth lining. Auxiliary secondary windings, D, consisting of a few turns of heavy copper strip closely surrounding the primary, are connected, and supply current to, the pole plates. These auxiliary windings, being close to the primary, minimise magnetic leakage, and the additional power consumed in the refractory material pole plate covering results in but little increase in self-induction. The net result is a great improvement in the power factor. Owing to the large volume of the well and to the heat developed at the pole plates, the Röchling-Rödenhauser furnace can be utilised satisfactorily for refining. Slag is prevented from entering the narrow circular sections of the hearth by baffles let into the roof and dipping below the level of the metal.

So much ingenuity has been displayed in the construction of electric steel furnaces that it seems unlikely that future advances in design will be of a

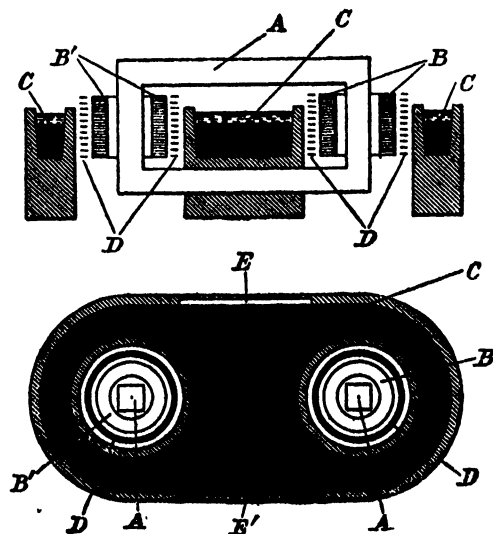


FIG. 44.

fundamental nature. It is more probable that improvements will relate to matters of detail connected with electrical supply, electrodes and their fittings and control, doors, linings, framework, tilting gear, improvement of the ratio $\frac{\text{power}}{\text{furnace capacity}}$, increase in furnace capacity, etc. In one direction, however, there is possibly scope for a radical advance in design, namely in connection with the better co-operation of fuel and electrically generated heat in the refining of pig iron and melting and refining of cold scrap. The advantages of the Duplex process, i.e., open-hearth treatment finished off by the electric furnace, are fully recognised. There seems to be no reason why the whole process should not be carried out in a single unit, at a considerable saving of heat and capital and labour charges. In dealing with cold charges, approximately 600 to 700 K.W.H. per ton is required to melt and refine to crucible quality one ton of scrap steel of open-hearth quality. Of this amount about 500 K.W.H. are expended in melting alone, an operation which, if carried out in the open-hearth furnace, would reduce the consumption of electrical energy to below 150 K.W.H. per ton of steel of crucible quality produced from cold open-hearth quality scrap.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

- MONDAY, OCTOBER 17.** Chadwick Public Lectures, at the Hastings Hall, British Medical Association, Tavistock Square, W.C. 5.15 p.m. Malcolm Morris Memorial Lecture. Dr. W. G. Savage, "Food Poisoning."
- East India Association, at the Caxton Hall, Westminster, S.W. 3.30 p.m. Mr. Sachchidananda Sinha, "Dyarchy in Indian Provinces: in Theory and Practice." (Resumed discussion).
- Public Health, Royal Institute of, 37, Russell Square, W.C. 4 p.m. Prof. Dr. R. Bruynoghe, "The Twort-d'Herelle Phenomenon." (Lecture I.)
- University of London, at University College, Gower Street, W.C. 5 p.m. Mr. R. J. Lythgoe, "Vision." (Lecture III.)
- TUESDAY, OCTOBER 18.** Academy of Arts, Royal, Burlington House, W. 4.30 p.m. Prof. Dr. Arthur Thomson, "Anatomy—The Lower Limb. Its Connection with the Trunk: Bones and Muscles studied in association with the Surface. Forms in Action and Repose—Part I."
- Asiatic Society, Royal, 74, Grosvenor Street, W.1. 4.30 p.m. Prof. Dr. Albert von Le Coq, "Journey and Results of the 4th Turfan Expedition."
- Automobile Engineers, Institution of, at the Engineering and Scientific Club, Wolverhampton, 7.30 p.m. Major E. G. Beaumont, "The Influence of the Automobile User upon the Automobile Engineer."
- Physicians, Royal College of, Pall Mall East, S.W. 4 p.m. Sir William Hale-White, K.B.E., M.D., Harveian Oration.
- Public Health, Royal Institute of, 37, Russell Square, W.C. 4 p.m. Prof. Dr. R. Bruynoghe, "The Twort-d'Herelle Phenomenon." (Lecture II.)
- University of London, at the Institution of Civil Engineers, Great George Street, Westminster, S.W. 5.30 p.m. Prof. Dr. Adolf Nagel, "Heat Transfer in Reciprocating Engines, including Internal Combustion Engines." (Lecture III.)

- Zoological Society, Regent's Park, N.W. 5.30 p.m. Scientific Business Meeting.
- WEDNESDAY, OCTOBER 19.** Microscopical Society Royal, 20, Hanover Square, W. 8 p.m.
- Public Health, Royal Institution of, 37, Russell Square, W.C. 4 p.m. Prof. Dr. S. Lyle Cummins, "Tuberculosis as a Social Disease."
- University of London, at University College, Gower Street, W.C. 5 p.m. Mr. R. J. Lythgoe, "Vision." (Lecture IV.)
- THURSDAY, OCTOBER 20.** Chemical Society, Burlington House, W. 8 p.m.
- Constructive Birth Control, Society for, at Essex Hall, Strand, W.C. 8 p.m. Prof. Julian S. Huxley, "The Population Conference at Geneva."
- Electrical Engineers, Institution of, Savoy Place, W.C. 6 p.m. Mr. Archibald Page, President's Inaugural Address.
- Metals, Institute of, at the Engineers' Club, Waterloo Street, Birmingham, 7 p.m. Dr. F. W. Aston, F.R.S., "Isotopes."
- Public Health, Royal Institute of, 37, Russell Square, W.C. 4 p.m. Prof. Dr. R. Bruynoghe, "Some New Research on Relapsing Fever."
- Tropical Medicine and Hygiene, Royal Society of, 11, Chandos Street, W. 7.45 p.m. Prof. Dr. J. W. Stephens, President's Inaugural Address, "The Functions of the Spleen."
- FRIDAY, OCTOBER 21.** Mechanical Engineers, Institution of, Storey's Gate, S.W. 6 p.m. Sir Henry Fowler, K.B.E., LL.D., Presidential Address.
- University of London, at University College, Gower Street, W.C. 5 p.m. Mrs. P. M. T. Kerridge, "Hydrogen Ion Concentration." (Lecture II.)
- At the Institution of Civil Engineers, Great George Street, Westminster, S.W. 5.30 p.m. Prof. Dr. Adolf Nagel, "Heat Transfer in Reciprocating Engines, including Internal Combustion Engines." (Lecture IV.)
- SATURDAY, OCTOBER 22.** L.C.C. The Horniman Museum, Forest Hill, S.E. 3.30 p.m. Mrs. H. M. Dunn. "The Peoples of India."

JOURNAL OF THE ROYAL SOCIETY OF ARTS

No. 3909.

VOL. LXXV.

FRIDAY, OCTOBER 21st, 1927.

*All communications for the Society should be addressed to the Secretary, John Street,
Adelphi, W.C. (2.)*

NOTICES.

OPENING OF THE 174th SESSION.

The Opening Meeting of the 174th Session will be held at 8 p.m. on Wednesday, November 2nd, when the Inaugural Address will be delivered by SIR PHILIP MAGNUS, Bt., Chairman of the Council. The subject will be "The Royal Society of Arts : its Services to Trade and Training."

After the delivery of the Address, the Society's silver medals awarded for papers read last session will be presented.

COUNCIL.

A meeting of the Council was held on Monday, October 10th. Present :— Sir Philip Magnus, Bt., in the Chair ; Sir Charles H. Armstrong ; Mr. Llewelyn B. Atkinson, M.I.E.E. ; Sir Charles Stuart Bayley, G.C.I.E., K.C.S.I. ; Captain Sir Arthur Clarke, K.B.E. ; Sir William Henry Davison, K.B.E., D.L., M.P. ; Mr. Peter MacIntyre Evans, M.A., LL.D. ; Rear-Admiral James de Courcy Hamilton, M.V.O. ; Sir Thomas Holland, K.C.S.I., K.C.I.E., D.Sc., F.R.S. ; Major Sir Humphrey Leggett, R.E., D.S.O. ; Sir Reginald A. Mant, K.C.I.E., C.S.I. ; Sir Richard Redmayne, K.C.B. ; Mr. Alan A. Campbell Swinton, F.R.S. ; Mr. Carmichael Thomas ; Professor J. M. Thomson, F.R.S., and Sir Frank Warner, K.B.E., with Mr. G. K. Menzies, M.A. (Secretary of the Society).

Particulars of the will of the late Henry Morley who appointed the Society joint residuary legatee of his estate, were reported.

[A notice of the bequest was printed in the *Journal* of July 29th, 1927, page 884].

The scheme for a Staff Superannuation Scheme was further considered.

Mr. James H. Hyde, Grand Officer, Legion of Honour, was elected a life Fellow of the Society under the terms of Bye-Law 53.

The following candidates were duly elected Fellows of the Society:—

Ahmad, Mohammad Basheer, M.A., London.
 Altham, Thomas Fielding, Stafford.
 Baronides, R. de Rohan, M.D., San Francisco, Cal., U.S.A.
 Bayliss, Arthur, A.M.I.Mech.E., Shetfield.
 Blair, Anthony Thomas, Grange-over-Sands, Lancs.
 Bradley, Harry L., Milwaukee, Wisconsin, U.S.A.
 Brown, Charles H., Breckenridge, Texas, U.S.A.
 Commander, Captain Joseph Storey, Thundersley, Essex.
 Contractor, Dossabhoy Hormusjee, Bombay, India.
 Davis, Carl Raymond, London.
 Dawson, Horace Currey, Kisii, Kenya Colony, E. Africa.
 Dias, Vincent Emanuel, Malacca, Straits Settlements.
 Erquiaga, Ruben, Choquebamba, Peru, South America.
 Hall, David Patrick, Cairo, Egypt.
 Jordan, Frank Rutland, London.
 Jung Bahadur, Nawab Shah Rookh Yar, Poona, India.
 Kabali, Purshottam Meghji, Bombay, India.
 Keys, C. M., New York City, U.S.A.
 Lawrence, Francis Henry, London.
 Lovett, Edgar Odell, Ph.D., Houston, Texas, U.S.A.
 Martin-Kaye, Hugh William, London.
 Masi, Frank H., M.A., Norfolk, Virginia, U.S.A.
 Minter, Robert William, Bromley, Kent.
 Morrison, Laurence Henry, Gravesend, Kent.
 Morwood, P. H., Tinsley, Sheffield.
 Napier, William Esmonde Lennox, Auckland, New Zealand.
 Norman, John Warren Eric, Charing, Kent.
 Nuttall, Charles, Melbourne, Australia.
 O'Gorman, Colonel Mervyn, C.B., D.Sc., London.
 Ramchandran, U. S., Nagpur City, India.
 Reid, Eric F., Singapore, Straits Settlements.
 Roberts, Colonel Warren Russell, Chicago, Illinois, U.S.A.
 Sapru, H. N., B.A., Cawnpore, India.
 Schanck, Francis Raber, Portland, Oregon, U.S.A.
 Simpson, Alexander Victor, M.I.R.E., Burnley, Lancs.
 Thomson, James Albert, London.
 Wagner, Anthony Richard, London.
 White, Harold F., Bald Blair, New South Wales, Australia.
 Wilson, John, Birmingham.

The arrangements for the forthcoming session were further considered.

It was reported that a meeting in connexion with the preservation of the Thomas à Becket Cottages at West Tarring would be held in the Connaught Hall, Worthing, on Thursday, November 3rd. (See page 1154.)

Other formal and financial business was transacted.

THE PRESERVATION OF ANCIENT COTTAGES

PUBLIC MEETING AT WORTHING.

The Mayor of Worthing has called a Public Meeting in the Connaught Hall, Worthing, on Thursday, November 3rd, at 3 p.m., to consider what steps can be taken to preserve the well-known Thomas à Becket Cottages at West Tarring. They are of the greatest possible beauty, and historic interest. Built about 1400 A.D., they are in a wonderful state of preservation, and are probably the finest specimens of their kind in the South of England. They were recently put up to auction, and would almost certainly have been demolished for the fine old oak which they contained had they not been temporarily rescued, thanks in large measure to a loan from the Society's Fund for the Preservation of Ancient Cottages.

Sir Frank Baines will deliver an illustrated address on "Ancient Cottage Architecture"; he will be supported by a number of influential residents in Worthing and the neighbourhood, and it is hoped that means will be found to render the cottages permanently secure.

PROCEEDINGS OF THE SOCIETY.

CANTOR LECTURES.

THE MEASUREMENT OF LIGHT.

By JOHN W. T. WALSH, M.A., D.Sc., F.Inst.P., A.M.I.E.E.,

Senior Assistant, National Physical Laboratory, and General Secretary,
International Commission on Illumination.

LECTURE I.—*Delivered April 25th, 1927.*

HISTORICAL.

It is always interesting, before beginning a survey of the modern methods adopted for any type of measurement, to consider briefly the history of the subject. The history of light measurement, or photometry as it is generally called, is by no means devoid of interest. As is, perhaps, to be expected, the first workers in photometry were the astronomers. As far back as the middle of the second century Ptolemy recorded in his great work on the stars, the *Almagest*, the relative intensities, or magnitudes as they are now termed, of the heavenly bodies. Centuries later the great Dutch physicist and astronomer Huyghens, in his book, "*Cosmotheoros*," gave an account of some fairly accurate measurements of the relative magnitudes of some of the heavenly bodies.

These astronomical estimations were, however, hardly photometric measurements in the sense in which we use the words to-day, and it is generally agreed that probably the first photometric experiment was carried out by a Frenchman named Pierre Bouguer early in the eighteenth century. Bouguer was a mathematician and was professor of hydrography at Havre from 1730. In 1735 he went with Condamine to Peru in order to measure a degree of the meridian near the equator and he subsequently published a book on the form of the earth. In 1729 he published a small treatise entitled "*Essai d'optique sur la gradation de la lumière*," and this event is generally regarded as marking the birth of the science of photometry. Actually, however, the photometer described in this book was used by Bouguer at least four years previously. He described to the French Academy of Sciences* how, on 23rd November, 1725, at half-past ten in the evening, he made a measurement of the illumination given by the full moon. The instrument which he used, generally known as Bouguer's photometer, is shown in Fig. 1. It is described more fully in the

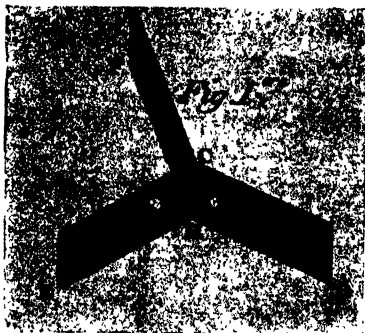


FIG. 1. Bouguer's Photometer.

larger book, "*Traité d'optique sur la gradation de la lumière*," written by Bouguer and published two years after his death by his friend the Abbé de la Caille. The two small circular apertures were covered with translucent paper and each was illuminated by one of the two sources of light to be compared. In the case of Bouguer's original measurement, the moonlight fell on one aperture while the other was illuminated by means of four candles. Bouguer found that the two translucent sheets appeared equally bright when the candles were placed at a distance of about 41 feet from the aperture they illuminated.

It was with this apparatus that Bouguer made a measurement of the least difference of brightness which the eye could just perceive. It is interesting to note that, although this quantity has been measured repeatedly since Bouguer's time, with results varying from $1/50$ to $1/167$, the present accepted

* *Histoire de l'Acad. Roy. des Sci.*, Paris, 1726, p. 11.

value of 1.6 per cent. is almost exactly that which Bouguer found with his comparatively crude photometer, viz., $1/64$.

Following Bouguer very closely was the German writer, Johann Heinrich Lambert, who was a really brilliant mathematician and who was responsible for the introduction of hyperbolic functions into mathematical analysis. It is strange that in 1760, the very year of publication of Bouguer's larger work. Lambert should have published his book "Photometria," in which he described the somewhat different form of photometer generally known by his name. This photometer is shown in Fig. 2. The pair of candles at A throw a shadow



FIG. 2. Lambert's Photometer.

of the board H on the portion of the wall marked CDEF while the candle N throws a similar shadow at BDFG. Thus each half of the wall is illuminated by one of the sources to be compared, and by adjusting the distances of these sources from the wall, the latter may be caused to have the same brightness over both halves. The value of Lambert's book, however, rests less on his description of a photometer than on the experiments which he gives and the deductions he draws from them. He enunciated very clearly the fundamental laws of photometry. These are (i) that illuminations are additive, (ii) that the illumination due to a source of light varies inversely as the square of the distance from the source, and (iii) that the illumination of a surface varies as the cosine of the angle which the normal to that surface makes with the direction of incidence of the light.

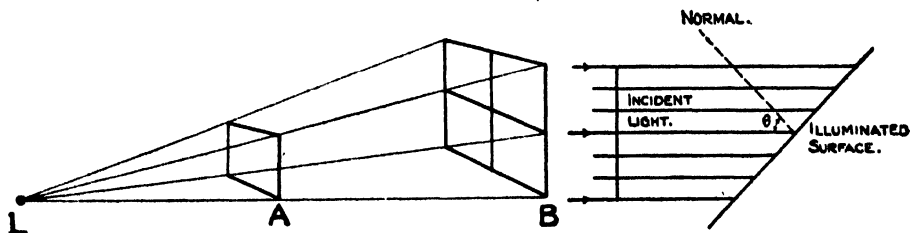


FIG. 3. The inverse square and cosine laws.

The second law will be clear from Fig. 3. If L be a lamp it is clear that the light which illuminates any given area at A will illuminate an area four times as great at B, if LB is twice LA. This simple example is sufficient to

demonstrate the truth of the proposition which Lambert was the first to prove experimentally.

Similarly, the effect of inclining a surface to the oncoming light is to cause the light to be distributed over an area which is larger in the ratio of the secant of the angle between the rays of light and the normal to the surface. Clearly it follows that the illumination varies as the cosine of this angle.

On these three laws enunciated by Lambert, the whole science of photometry is based.

The next notable contribution to the subject was made by that great American, Benjamin Thompson, afterwards Count Rumford. Rumford had a very romantic career. He was born in Massachusetts and fought with the English forces in the American War of Independence. After the evacuation of Boston he came to England and later on entered the service of the Elector of Bavaria, who created him Count Rumford. He was at that time interested in the management of a kind of workhouse which he had established in Munich, and it was in connection with the lighting and heating of this building that he carried out his famous experiments on heat and invented the photometer known by his name. He sent a description of his photometric work to the then Secretary of the Royal Society, Sir Joseph Banks, who considered it of sufficient interest to be communicated to the Society and printed in the "Philosophical Transactions."

Rumford introduced a unit of candle-power which he termed a "degree of light." This was the one-hundredth part of the luminous intensity of a wax candle burning at the rate of 108 grains per hour. Rumford later returned to England and devoted his time and fortune to scientific research. In 1799 he founded the Royal Institution. His memory is preserved by the Rumford medal of the Royal Society and a similar distinction awarded annually by the American Academy of Arts and Sciences, both being given for original research in light or heat.

The Rumford photometer—although it has frequently been described quite wrongly in text-books in which accuracy has been sacrificed to brevity—is, when properly constructed and used, capable of giving very good results. There is not space to describe the various modifications of the Bouguer or of the Lambert-Rumford photometers which have been used by various workers in the subject. The most noteworthy are, perhaps, the Foucault instrument used by Dumas and Regnault in their study of the lighting of Paris, and the Gas Referees' photometer used until lately for testing the illuminating power of gas in the Metropolitan area. Extinction photometers, in which a measure of intensity was made by observing the number of sheets of a semi-transparent material, such as horn, which could be interposed between the eye and the source before the latter disappeared, hardly deserve the name of photometers. An instrument of this kind was certainly used in 1700 and it has been invented repeatedly since that time. Such photometers have,

however, done good service until quite recently in astronomical photometry.

The next distinct advance was made by William Ritchie, who, after many attempts to adapt the differential thermometer to the comparison of light sources, devised the form of photometer head which is generally known by his name. In its first form, shown in Fig. 4, this photometer was a modification of Bouguer's. Two pieces of mirror, CF, FD, reflected the light from the sources to the translucent paper EG. Ritchie, however, also used the same form of head without the translucent paper, pasting opaque matt white paper over the mirrors, and comparing the brightness of these two surfaces directly. The prism, CFD, which is generally known as the Ritchie "wedge," has formed the basis of many instruments, each designed generally with the object of producing as sharp and fine a division as possible between the surfaces, for this was early recognised as being an important feature in accurate photometry.

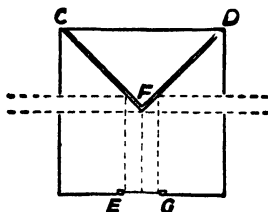


FIG. 4. Ritchie's Photometer.

It will have been noticed that all the photometers so far described have the same principle underlying them. Two adjacent white surfaces, or neighbouring portions of a single surface, are respectively illuminated by the light from two sources. One of these sources is moved towards or away from the photometer surface so that the brightness of this surface is increased or diminished. The eye of the observer is required to judge when the two surfaces appear equally bright, and the fundamental laws of photometry are then used to obtain the relative luminous intensities (or candle-powers as we have been used to call them) of the sources. In Ritchie's photometer, for instance, the wedge may be mounted somewhere near the middle of a bench, the two sources being placed one on each side of it. The relative positions of the two sources and the photometer head are then altered until both sides of the wedge appear equally bright when viewed from the front. Assuming that the wedge is symmetrical or, in other words, that equal illuminations on the two sides result in equality of brightness, it follows that the relative candle-powers of the sources can be found immediately by measuring their distances from the photometer head. By the inverse square law, if I_1 and I_2 be the candle powers and d_1 and d_2 the corresponding distances, then

$$I_1/d_1^2 = I_2/d_2^2$$

It will be seen later that this simple method of measurement is open to serious

objection in practice, but it serves to show the underlying principle of most candle-power measurement, *i.e.*, the matching of the photometer field by the alteration of the distance between one source and the photometer, and the use of the inverse square law.

Modern forms of photometer head, and more accurate methods of measurement on the bench will be described in the next Lecture, but there are two matters of great importance which it is desirable to notice at this stage. In the first place, it was clearly recognised by Bouguer, and has been accepted by every worker in photometry since his day, that the eye cannot judge of the relative brightness of two surfaces when these brightnesses are unequal. In other words, it cannot measure. All visual photometry, therefore, must depend on a judgment of *equality* of brightness. Secondly, the precision with which the eye can make this judgment as to the equality of brightness of two surfaces is greatly reduced if they are separated from each other either spatially or temporarily. In other words, the surfaces must be seen simultaneously* and side by side, with the finest possible line of demarcation between them. This principle is of the utmost importance and must be remembered when any system of photometric measurement is being considered. There is a third condition, *viz.*, that the surfaces must be of suitable brightness. This will be considered in more detail later in this lecture.

GENERAL PRINCIPLES.

The measurement which is almost invariably associated with the idea of photometry is that of candle-power, *i.e.*, the light-giving power of a source in a given direction. The name of this unit is derived from the source originally used as a standard. The luminous intensity of sources was for a long time measured by comparing them on a photometer bench with a candle of specified material and weight burning at a specified rate. The number of such candles to which the source was equivalent in light-giving power was termed the "candle-power" of the source. Later on, the candle was found to be too variable for accurate work and was superseded in different countries by flame lamps of various forms. The best known are the Hefner lamp, which burns amyl acetate and is the standard still legal in Germany, the colza-burning Carcel lamp, which was long used in France, and the Vernon-Harcourt Pentane lamp recognised in this country for many years. Many other forms of standard source have been proposed at various times, but none are reproducible to the accuracy of photometric measurement. In consequence of this state of affairs the national standardizing laboratories of France, Great Britain and the United States, agreed in 1909 to adopt a unit which was actually, as far as could be ascertained, the unit then in use in this country as it was incorporated in the Pentane lamp. A number of very carefully prepared

*An exception is made in the case of the flicker photometer in which there is a rapid alternation between the two surfaces.

electric lamps of special construction were measured in terms of this unit and were then deposited at the different laboratories. Other lamps, measured by comparison with these, have been exchanged between the laboratories since 1909 to ensure that the original standards have maintained, unaltered, their candle-powers as then determined. The last comparison between this country and America was carried out only two years ago and showed that no change exceeding 1 part in 1,000 had taken place.

This result is exceedingly satisfactory since it indicates that the unit has been maintained to an accuracy equal to that attainable in the highest precision photometry.

Nevertheless, the preservation of the unit of light by any means other than a standard source reproducible from specification is not free from objection on scientific grounds, and there is no doubt that the search for a satisfactory primary standard must go on. In three countries, at least, the use of a hollow enclosure held at a specified temperature is being studied. Provided this temperature can be reproduced with sufficient accuracy, a small aperture in the enclosure has a definite candle-power per unit area. This form of standard, if obtainable, would be eminently satisfactory, but, unfortunately, the accuracy of temperature determination at the comparatively high temperatures required, is not sufficient to give the candle-power a reproducibility equal to that attainable by the use of electric lamps. An alternative form of primary standard which is also being studied is the positive crater of a carbon arc operating under carefully controlled conditions.

At the present time, then, the unit of candle-power, or luminous intensity as it should be called, is the international candle based on the measurement of certain electric lamps in carefully defined directions. This is the unit used to express the light-giving power of a source in a single direction. It must always be remembered, however, that every practical source of light has a non-uniform light distribution, so that to speak of its "candle-power" without specifying the direction in which that candle-power is measured is, strictly speaking, quite meaningless. It is true that in many cases the luminous intensity is approximately uniform over a given group of directions which happen to be of the greatest importance from the practical point of view. In such cases the expression is useful if its conventional nature be carefully borne in mind. As an example, it may be mentioned that the ordinary tungsten filament vacuum lamp is very stereotyped in its filament arrangement, and this arrangement is such that the luminous intensity is nearly the same in all directions perpendicular to the axis of the lamp. It is, therefore, usual to associate with this type of lamp the candle-power figure in this particular direction. The same consideration applies to the upright gas mantle.

While this system of describing the light output of a lamp has been quite satisfactory until comparatively recently, two developments in lighting practice which have taken place, largely within the last 10 or 15 years, have

now made it imperative that a more precise method of light rating should be introduced. The filament of the modern gas-filled lamp may be disposed in a number of different ways, of which two, the ring and the festoon form, are common. The direction in which the candle-power is most regular is different in the two cases, and endless confusion would be caused if the light output of such electric lamps were to be described by means of the candle-power measured in any single direction or group of directions. Further, the very high brilliancy of the filament in a gas-filled lamp, and modern developments in the art of illumination, have made it usual to enclose the lamp in a shade, reflector or other fitting, so designed that the whole of the light emitted, no matter how it is distributed, is made use of to the best advantage. This means that under modern conditions, the performance of a lamp must be gauged by its total light output. It is necessary, therefore, to have a unit in terms of which it is possible to measure this quantity.

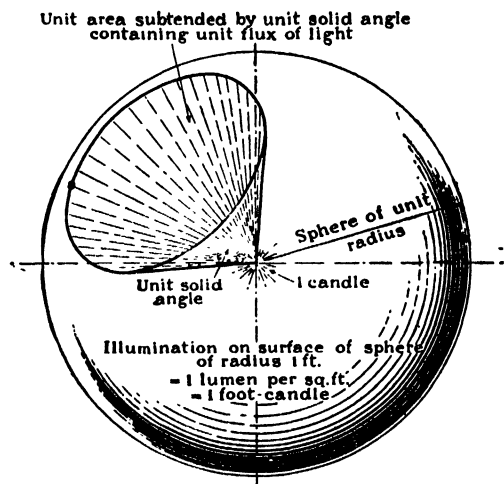


FIG. 5. Luminous flux and the Lumen.

This unit may be derived from the candle by imagining a source of light having a uniform luminous intensity of one candle, placed in the centre of an imaginary hollow sphere of which a portion equal in area to the square on the radius has been removed (see Fig. 5). The amount of light emitted by the source through the aperture thus created is the unit of light output, or preferably luminous flux, which has been adopted, and this unit is called a lumen. Clearly such a unit can be used to express the luminous flux output of any source whatsoever, whether its candle-power be uniform or not.

Since the total area of the surface of a sphere is equal to about 12.6* times the square on its radius, the total number of lumens emitted by a source having a candle-power of unity is equal to 12.6 lumens. Now the total number of

*Accurately, 4π .

lumens emitted is unaffected by the way in which the light is distributed, and it is clear, therefore, that the total number of lumens given by a source is equal to the average value of its candle-power, measured in all directions in space, multiplied by the factor 12.6. This average is often called the mean spherical candle-power of the source since it may be obtained by taking the average of the values of candle-power measured in a large number of directions equally disposed about the source. The number of lumens given by a lamp, therefore, is equal to the mean spherical candle-power of the lamp multiplied by 12.6.

It may appear that this matter has been unnecessarily elaborated, but it is so frequently a cause of confusion that a little time devoted to its elucidation is by no means wasted.

Once the terms luminous intensity and luminous flux, and their relationship to each other, have been defined, the other primary photometric units, viz., illumination and brightness, can be described quite simply. When luminous flux from a light source reaches a surface that surface is said to be illuminated, and the illumination is measured by the amount of flux which reaches the surface per unit area. Referring again to Fig. 3, it will be seen now how simply the conception of luminous flux fits in with the inverse square and cosine laws which lie at the root of all photometric measurement. The unit of illumination employed in this country is the foot-candle, and this is the illumination which is produced when one lumen of flux is uniformly distributed over one square foot of the surface. Similarly, the metric unit of illumination, the metre-candle or lux, is the illumination produced when one lumen of flux is uniformly distributed over one square metre of a surface. As an example of the magnitude of these units it may be mentioned that the illumination of this table is about three foot-candles or 30 metre-candles.

It is interesting to notice that the foot-candle may also be defined as the illumination of a small surface placed at a distance of one foot from a source of unit candle-power, provided the surface is perpendicular to the light rays. It is easy to show that these two definitions of the foot-candle are really identical by considering once more the diagram of Fig. 5. If the radius of the sphere be one foot, the area removed is one square foot. The illumination of the inner surface of the sphere is then equal to one lumen per square foot, *i.e.*, to one foot-candle. The same result is arrived at by considering the fact that every part of the surface is at a distance of one foot from the unit source placed at the centre.

The last of the four fundamental photometric quantities is brightness. Any object, whether it be self-luminous or not, is seen by the light which it sends to the eye. The brightness of the surface is proportional to its luminous intensity per unit projected area. Thus if a flame of uniform brightness has an apparent area of one square inch when viewed in a given direction, and if the luminous intensity in that direction be 10 candles, the brightness is 10 candles per square inch. Similarly, if a piece of paper has an area of two

square feet, and if its brightness, when viewed broadside on, is one candle per square foot, it has a luminous intensity of two candles in the direction of the normal to the paper.

Surfaces are divided broadly into two classes, polished and diffusing, according as they reflect light specularly after the manner of a mirror, or scatter it in all directions. A surface which scatters the light which it reflects or emits in such a way that it appears equally bright from whatever direction it is viewed, is called a perfect diffuser. While no such surface actually exists in perfection, certain surfaces, such as good blotting-paper, ground opal glass and powdered magnesium oxide or carbonate, approach this ideal state comparatively closely.

Although, as has been said, no actual surface appears equally bright in all directions, it is sometimes convenient to express the brightness of a given surface when viewed from a given direction in terms of the brightness of an ideal perfectly diffusing surface which emits or reflects one lumen per square foot. This unit of brightness is called the "foot-lambert," and it can be shown that a brightness of one candle per square foot is equal to 3.14 (*i.e.*, π) foot-lamberts.

It is easy to see that, since a surface having an illumination of one foot-candle receives one lumen per square foot, its brightness would be one foot-lambert if it were a perfect diffuser and if all the light were reflected. Actually all surfaces absorb some of the light they receive, and the fraction of the incident flux which is absorbed is called the absorption factor. Similarly the fraction reflected is called the reflection factor. A piece of white blotting paper and a good silvered-glass mirror both have a reflection factor of 85 to 90 per cent., *i.e.*, only about 10 to 15 per cent. of the light which they receive is lost by absorption. It follows that a piece of white blotting paper, of which the illumination is one foot-candle, has a brightness of about 0.9 foot-lamberts, since, for most practical purposes, this surface may be regarded as a fair approximation to a perfect diffuser.

There is still one more term to be defined. The reflection and absorption factors of a surface have already been mentioned. In the case of a transparent medium, part of the incident light is transmitted and the fraction transmitted is called the transmission factor.

METHODS OF LIGHT MEASUREMENT.

From a consideration of the units employed in the measurement of light it is convenient to pass on to a general description of the different methods used. It has been said already that the eye can only judge the equality of brightness of two surfaces, and every photometer, therefore, is a combination of two principal parts. The first consists of some device for enabling the eye to compare as accurately as possible the brightness of two surfaces, one of these being illuminated by the source to be measured. The other part is a means

for varying the brightness of the other surface according to some known law, so that the two can be adjusted to equality. It is convenient to classify photometric methods and apparatus according to the method used for obtaining the variation of brightness of one of the two comparison surfaces. By far the most usual method is to vary the distance of a controlled source from the surface, and to use the inverse square law. This is the procedure generally adopted on a photometer bench. There are, however, circumstances in which such a procedure is inconvenient or impossible, and then some other method must be used to obtain the necessary variation of brightness. The most obvious method under these conditions is to make use of the cosine law, and to incline the comparison surface so that the light reaches it more or less obliquely. This method is open to considerable objection from a practical point of view, and although the variation of brightness is obtained by tilting in some portable photometers, the law of variation of brightness with angle of tilt is not a true cosine law, but has to be obtained empirically.

By far the most accurate method of variation, after the use of the inverse square law, is that of the sector disc. If an opaque disc has a radial slot cut in it, and if this disc be mounted between a source of light and a surface so that the light only reaches the surface as the slot passes between the two, then as the disc is rotated the illumination of the surface flickers until the speed of the rotation has reached a certain value. Above this speed, which naturally depends on the breadth of the slot, the eye ceases to detect the flicker, and the brightness of the surface is strictly proportional to the angular breadth of the slot. Thus, if the slot were 36° wide, the brightness of the surface would be only one-tenth of what it would be if the disc were entirely removed.

The law that expresses this proportionality between brightness and breadth of slot is so simple that it might mistakenly be regarded as self-evident. A moment's consideration, however, will show that this is not the case, for it is well known that the action of the eye is by no means instantaneous. It requires time to perceive a given light, and an impression once received takes time to die away. These effects, however, are found to balance out in practice, and the result is the law which has just been described and which is generally known, after its discoverer, as Talbot's Law.

The law is of such importance in photometric work that it has been tested over a very wide range. It has been found impossible to detect any failure of the law to within the unavoidable errors of experiment. At very narrow widths of slot these errors become so large that no really adequate test can be made.

The simplest form of sector disc is a single disc with three or more slots cut in it to reduce the speed at which flicker disappears. Such discs, with a factor of one-tenth or one-twentieth, are exceedingly valuable as auxiliaries to other photometric apparatus, but it will be clear that as their reduction ratio is fixed, they cannot themselves be used to produce the variation of brightness

needed in a photometer. For this purpose some form of disc with variable sectors is needed, and many attempts have been made to produce satisfactory apparatus of this kind. There are, however, certain difficulties to be overcome. The variable slot is produced by having two discs moving one over the other, but the design of a mechanism which will allow this motion to be made with slight manual effort and without back-lash while the combination is running at, say, 2,500 revolutions per minute, is far from simple. Further, means must be provided for reading the size of the opening when a balance has been made, or else the disc has to be stopped after every setting.

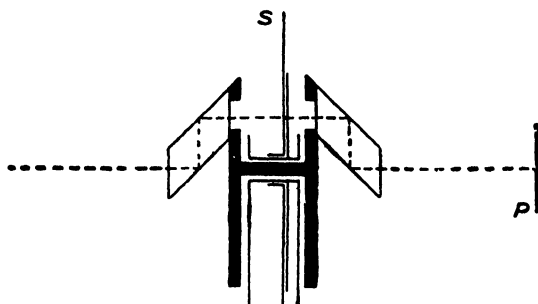


FIG. 6. The Brodhun Sector Disc

Probably the most satisfactory type of variable sector disc is that in which the disc remains stationary while the beam of light rotates. Fig. 6 will show the principle of the apparatus. The light from the lamp is reflected twice, as shown by the broken line, traverses the slot in the disc *S* and is again reflected so that it resumes its original direction. The reflecting surfaces may be mirrors or, preferably, the 45° surfaces of rhomboidal prisms as illustrated. In any case the four are rigidly fixed to one another in the relative positions shown, and the combination is rotated about its axis. It will be seen that the effect at the photometer surface *P* is precisely equivalent to that which would be produced by lowering the disc and spinning it in the usual way. As, however, the disc remains stationary, there is no difficulty whatever in making it easily adjustable by the observer at the photometer, while a setting can be at once read off by having a scale on one disc and an index line on the other.

The chief disadvantage of this apparatus is that large prisms are required if the surface *P* is to be of the size ordinarily used in precision photometry, while if the reflecting surfaces are mirrors, there is a danger of change in their reflection factors, for it will be clear that the light reaching *P* is diminished not only on account of the sector disc effect, but also by the absorption of light in the rotating system.

Yet another method of obtaining a variable brightness of the comparison surface in a photometer is to insert between this surface and the lamp illuminating it a transparent medium of variable transmission. Such a medium frequently takes the form of a so-called "wedge" of neutral glass. Alterna-

tively a wedge of celluloid containing very fine carbon particles suspended in it is often used, or a strip of exposed photographic film the density of which increases continuously from one end to the other. In any case the "wedge" has to be calibrated so that its transmission factor is known at each part. The wedge is then moved slowly across the beam of light between the lamp and the photometer surface until a balance is obtained.

A somewhat different device is that used in many spectrophotometers. It consists of two nicol prisms. This type of prism produces a beam of polarised light from an unpolarised beam, and if one such prism be placed in the path of the light from a lamp, the transmitted light is plane polarised. If, now, a second nicol be placed in the path of this polarised beam, its transmission varies as $\cos^2\theta$ where θ is the angle between the corresponding planes of the two prisms. It is clear that, by having such a pair of prisms between the lamp and the photometer surface, if one prism is fixed and the other capable of rotation, the intensity of the light reaching the surface is varied according to a known law when the second prism is rotated.

Finally, the candle-power of the lamp itself may be varied in some way. In the case of an electric lamp this variation may be brought about by varying the current passing through the filament, but, unfortunately, the colour of the light given by the lamp is altered at the same time as the candle-power, so that the brightness comparison becomes very difficult. A better alternative is to place a piece of diffusing glass or similar material close to the lamp, so that it has a high and *uniform* brightness. This diffusing glass becomes the source of light illuminating the photometer surface and clearly its intensity, and therefore the illumination of the surface, is proportional to the area of the diffusing glass exposed. A diaphragm of variable aperture placed in front of this diffusing surface gives a source of variable candle-power such as is needed.

An alternative method is to form an image of the diffusing glass on the photometer surface by means of a lens and to place the variable diaphragm over the lens. This method is particularly useful when the luminous intensity of the diffusing surface is small.

THE EYE.

It will be clear, from what has been said already, that the precision of all photometric measurement is entirely dependent on the eye, and its sensitivity to small differences of brightness. It is not surprising, therefore, that this characteristic of the eye has been carefully studied by many workers interested in photometric problems. The sensitivity is usually expressed in the form of a fraction, *viz.*, the brightness difference which the eye can just perceive measured as a percentage of the general brightness of the field of view. This method of description is convenient since it has been found that over a wide range of brightness the sensitivity as thus defined is practically constant and

for a single eye is about 1.7 per cent. This constancy is in accordance with the law which holds approximately for all sensations and is known as Müller's Law. The first to apply it to vision and to study its variations in the case of the eye was G. T. Fechner, so that the fraction is generally known as Fechner's fraction.

While, as has been said above, this fraction is practically constant for a wide range of brightness, it rises slightly when the brightness becomes very great, and for low brightnesses it may become very large. The curve of Fig. 7

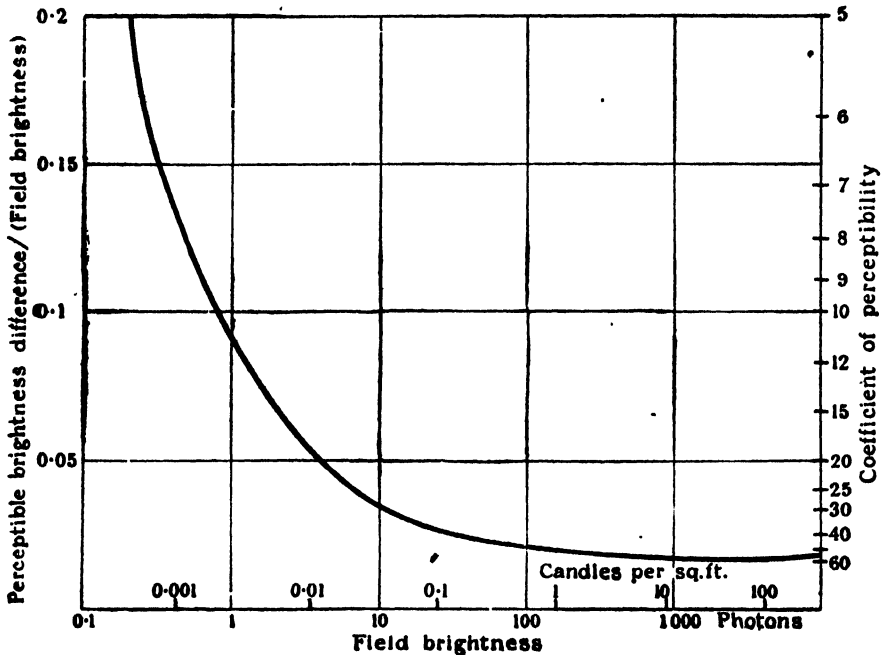


FIG. 7. The Variation of Contrast Sensitivity with Brightness.

shows the general trend of the variation of Fechner's fraction with field brightness. There is a slight complication which has to be considered here and which is due to the fact that the pupil of the eye changes its aperture according to the brightness of the object which the eye is viewing.

The variation of pupillary aperture with field brightness is shown in Fig. 8, and it will be seen that in considering the sensitivity of the eye it is necessary to state whether the field is viewed through the natural pupil or through an artificial pupil of fixed aperture. As is to be expected, the curve connecting pupillary aperture with field brightness is not exactly the same for all eyes, and it is therefore more convenient to measure Fechner's fraction under conditions corresponding to a fixed pupillary aperture of one square millimetre and to correct the curve so obtained to give the sensitivity under conditions of normal pupillary diameter for the average eye. This can easily be done

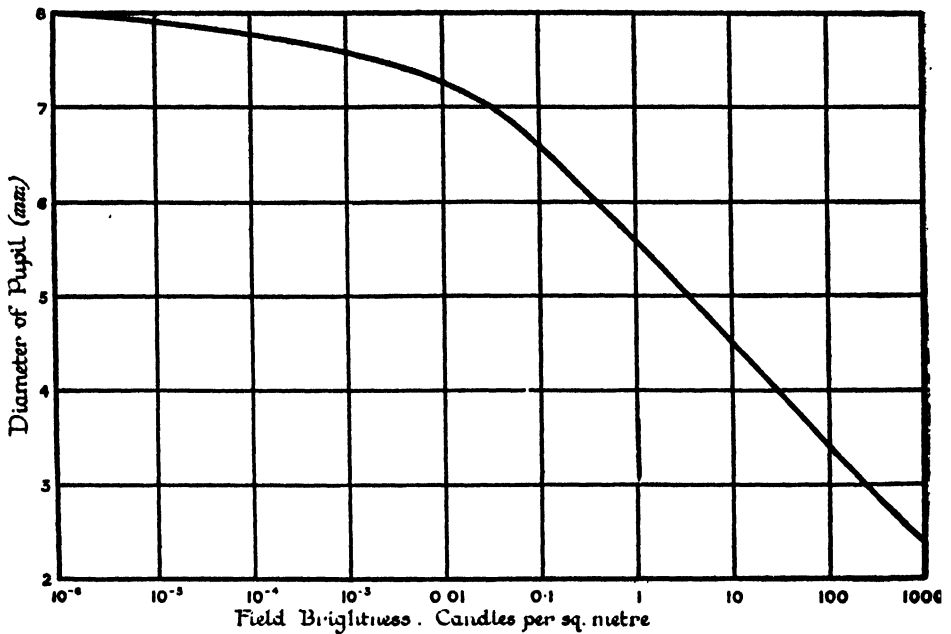


FIG. 8. The Variation of Pupillary Diameter with Brightness.

since the controlling factor is the brightness of the image formed on the retina and this is proportional to the aperture of the pupil. The lower scale of brightnesses in Fig. 7 is for an artificial pupil one square millimetre in area. The upper scale is of field brightness with a natural pupil, assuming the curve of Fig. 8 to represent the conditions for the average eye.

In ordinary photometric work the natural pupil is used up to a limit of about 10 square millimetres, which is the area of the artificial pupil in the ordinary Lummer-Brodhun photometer head. It will be seen from the curve of Fig. 7 that the lowest brightness at which it is possible to work without undue loss of sensitivity is about 0.3 candle per square foot, so that if the reflection factor of the illuminated surface in the photometer head be taken as 80 per cent., an illumination of at least 1.2 foot-candles is necessary. On account of losses by reflection at the glass surfaces used in the ordinary photometer head, a somewhat higher illumination than this is desirable. This is an important matter which will be referred to again later.

It might be concluded from the curve of Fig. 7 that the greatest precision attainable in photometry under the best conditions would be about 1.7 per cent., but a moment's consideration will show that this is not the case. For this figure represents the change from absolute equality which can be made before a difference becomes perceptible to the eye, so that there is a range of about $3\frac{1}{2}$ per cent. within which no brightness difference can be detected. When a photometric measurement is made, either by means of a photometer

head on the bench or by means of an illumination photometer, this range of $3\frac{1}{2}$ per cent. is passed through from one side to another and back again several times fairly rapidly, and an attempt is then made to adjust to the midway point between the two extremes. This mid-way point can certainly be judged much more closely than would at first sight appear possible. It is at this stage of the work that the design of the apparatus and the practised skill of the observer become important. Uniformity of field, a fine and sharp dividing line, and ability to pass rapidly and without manual effort from one side of the balance point to the other, are the primary requirements of any good photometer, and only in so far as they are fulfilled can the instrument be regarded as satisfactory for precise work.

There is one other characteristic of the eye which must be mentioned at this stage, *viz.*, its relative sensitivity to light at different parts of the spectrum.

The response of the eye to a given amount of energy depends on the wave-length of the radiation conveying that energy, or, in other words, on the colour of the light. The eye is most sensitive in the yellow-green, and its sensitivity diminishes rapidly as the ends of the spectrum are approached. The right-hand curve of Fig. 9 shows the relative amounts of luminous radiation which correspond to a given amount of energy at different wave-lengths when the field brightness is normal.

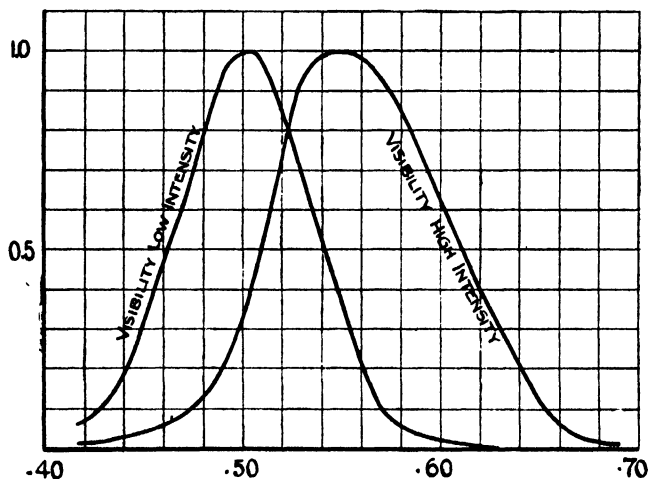


FIG. 9. The visibility curve.

If this curve were the same for every eye and under all conditions of brightness, it could be determined once for all and the photometry of sources giving lights of different colours would be much simplified. In actual fact the form of the curve differs slightly for every individual, and the curve shown in Fig. 9 is that which has been adopted internationally, after long experiment, as the best approximation to the average of normal-sighted observers. A much more serious complication is introduced by the fact that the form of the curve alters

radically when the brightness of the field of view falls below a certain value which is about 1.5 candles per square metre when viewed through the natural pupil. Below this point the maximum of the curve shifts towards the blue, and finally the curve takes up the form shown by the line marked "low intensity" in Fig. 9.

It will be seen at once that this effect is one of great importance from the point of view of photometry. It means that if two fields are illuminated, one by red and one by green light, for example, then it may quite well happen that when the brightness of both fields is high the red may appear the brighter of the two, while if both be reduced in brightness in the same ratio, the balance may appear to shift over so that the green may appear brighter than the red.

This effect is known as the Purkyne effect and it has to be guarded against, especially where the sources to be compared are not giving lights of exactly the same colour, by ensuring that the brightness of the field of view is above the limit of 1.5 candles per square metre mentioned above.

NOTES ON BOOKS

FLAME AND COMBUSTION IN GASES. By William A. Bone, D.Sc., Ph.D., F.R.S., and Donald T. A. Townend, Ph.D., D.I.C. London: Longmans, Green & Co., Ltd. 32s. net.

This volume constitutes a notable and welcome contribution to the study of one of the most perplexing branches of Physical Chemistry. Though an infinity of experimental work has been carried out in the investigation of gaseous combustion since the fundamental researches of Dalton and Davy, it is nevertheless the fact that no general review of the subject has ever been published; nor is the reason far to seek, since unfortunately it has proved singularly difficult in this field to formulate broad generalizations and unifying conceptions such as have been applied with marked success to the simplification of other obscure physico-chemical problems. Owing to this scarcity of illuminating general principles, the difficulty of reducing to some sort of order the immense mass of existing data is one that can hardly be exaggerated, and chemists may congratulate themselves that this task has now been performed by such an authority as Professor Bone.

The book is divided into five sections, which represent the divisions into which the subject seems naturally to fall at the present time. The first section consists of an historical review, the remainder of the volume being devoted to more modern developments, many of these being of very recent date. The phenomena observed in the early and later stages of gaseous explosions are described in the second section, and stationary flames, with their structure and radiations, are discussed. The next section treats mainly of the mechanical effects of gaseous explosions in closed vessels, whether under initial pressure or not, and contains an interesting chapter on the problem of "knock" in petrol engines. It has not proved possible, however, in the space available, to deal adequately with the effects of explosions under high initial pressure, and accordingly the authors propose shortly to publish, with the collaboration of Dr. D. M. Newitt, a supplementary volume discussing this question much more fully.

The two last sections are more definitely chemical in character. The fourth is concerned chiefly with the chemistry of the combustion of carbon and carbon

compounds, particularly with reference to the intermediate reactions involved ; and the last with catalytic and surface combustion, a subject on which Dr. Bone delivered the Howard Lectures to the Royal Society of Arts in 1914.

Certain minor errors seem to have escaped revision. It is a little surprising, for example, to find the form "*per saltem*" used several times over ; and used, furthermore, to characterize a process which takes place in several sudden leaps as opposed to one sudden leap, and to which, therefore, even the expression "*per saltum*" could not be applied very happily.

The general temper of portions of the book may perhaps be described as controversial rather than judicial ; but this furnishes no ground for criticism, since the bibliographical data are so excellent that any reader can easily study for himself at first hand the arguments of dissenting workers. The bibliographies alone, to say nothing of the valuable collection of tabulated numerical observations in the Appendix, must prove of the utmost value to any worker on gaseous combustion ; and it may be confidently predicted that research in this field will be stimulated and facilitated by the plain path which the authors have constructed through what has until now been very difficult country.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, OCTOBER 23. Automobile Engineers, Institution of, at the Royal Technical College, Glasgow. 7.30 p.m. Major E. G. Beaumont, "The Influence of the Automobile User upon the Automobile Engineer."

Electrical Engineers, Institution of, Savoy Place, W.C. 7 p.m. Discussion on "What is required to ensure the Comprehensive Distribution of Electricity," opened by Mr. Archibald Page (President). At the University, Liverpool. 7 p.m. Prof. Dr. F. J. Teago, Chairman's Address.

At Armstrong College, Newcastle-upon-Tyne. 7 p.m. Mr. H. Paterson, Chairman's Address.

Mechanical Engineers, Institution of, Storey's Gate, S.W. 6.30 p.m. Mr. John Rogers, "The Laquefaction of Air."

University of London, at King's College, Strand, W.C. 5.30 p.m. N. V. Arseniev, "The Orthodox Church and the Essence of Christianity." (Lecture I.) At University College, Gower Street, W.C. 5 p.m. Mr. R. J. Lythgoe, "Vision." (Lecture V.)

TUESDAY, OCTOBER 25. Academy of Arts, Royal, Burlington House, W. 4.30 p.m. Prof. Dr. Arthur Thomson, "Anatomy—The Lower Limb. Its connection with the Trunk. Bones and Muscles studied in association with the Surface Forms in Action and Repose." (Part II.)

Electrical Engineers, Institution of, at the Guildhall Derby. 6.45 p.m. Mr. A. E. McColl, "The Lanarkshire Hydro-Electric Scheme."

Photographic Society, 35, Russell Square, W.C. 7 p.m. Mr. Olaf Bloch, "Climbing Holidays and Bad photography in the Dauphiné."

University of London, at Bedford College for Women, Regent's Park, N.W. 5.15 p.m. Major Leonard Darwin, D.Sc., "Eugenics in the Future." At King's College, Strand, W.C. 5.30 p.m. N. V. Arseniev, "The Orthodox Church and the Essence of Christianity." (Lecture II.)

WEDNESDAY, OCTOBER 26. African Society, at the Royal Society of Arts, Adelphi, W.C. 3 p.m. Film. "The awakening of the equatorial Congo," by M. Ernest Gevaert. Lord Buxton in the Chair.

Automobile Engineers, Institution of, at the Engineers' Club, Albert Square, Manchester. 7 p.m. Major E. G. Beaumont, "The Influence of the Automobile User upon the Automobile Engineer."

British Academy, Burlington House, W. 5 p.m. Prof. F. M. Stenton, "The Danes in England." (Raleigh Lecture.)

Public Health, Royal Institute of, 37, Russell Square, W.C. 4 p.m. Prof. F. T. G. Hobday, "Some Diseases conveyed to Man from Animals and their Prevention."

University of London, at King's College, Strand, W.C. 5.30 p.m. N. V. Arseniev, "The Orthodox Church and the Essence of Christianity." (Lecture III.) At University College, Gower Street, W.C. 5 p.m. Mr. R. J. Lythgoe, "Vision." (Lecture VI.)

THURSDAY, OCTOBER 27. Chadwick Public Lecture, at 90, Buckingham Palace Road, S.W. 5 p.m. Mr. W. Hales, "Tropical Vegetation and some of its Uses to Man."

At the Victoria and Albert Museum, South Kensington S.W. 5.30 p.m. Mr. A. I. B. Wace, "Sheldon Tapestries."

FRIDAY, OCTOBER 28. Academy of Arts, Royal, Burlington House, W. 4.30 p.m. Prof. Dr. Arthur Thomson, "Anatomy. The Lower Limb. Its connection with the Trunk. Bones and Muscles studied in association with the Surface Forms in Action and Repose." (Part III.)

Chemical Engineers, Institution of, at the Institution of Civil Engineers, Great George Street, S.W. 6.30 p.m. Sir William Bragg, K.B.E., F.R.S., "Crystallisation."

Mechanical Engineers, Institution of, Storey's Gate, S.W. 7 p.m. Mr. Loughnan Pendred, "Engineering in the United States of America."

North East Coast Institution of Engineers and Shipbuilders, Bolbec Hall, Newcastle-upon-Tyne. 6 p.m. Mr. Maurice S. Gibb, Presidential Address. (Annual General Meeting.)

Philological Society, at University College, Gower Street, W.C. 8 p.m. Rev. F. D. Priestley-Evans, "Place-names in —minster."

Physical Society, at the Imperial College of Science, South Kensington, S.W. 5 p.m.

University of London, at Imperial College of Science, South Kensington, S.W. 5.30 p.m. Admiral Sir Reginald Custance, "Military Force as an Insurance." At University College, Gower Street, W.C. 5 p.m. Mrs. P. M. T. Kerridge, "Hydrogen Ion Concentration." (Lecture II.)

SATURDAY, OCTOBER 29. L.C.C. Horniman Museum, Forest Hill, S.E. 3.30 p.m. Mr. Montagu A. Phillips, "Nature at Home."

JOURNAL OF THE ROYAL SOCIETY OF ARTS

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VOL. LXXV.

FRIDAY, OCTOBER 28th, 1927.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2.)

PRESERVATION OF ANCIENT COTTAGES.

THOMAS À BECKET COTTAGES, WEST TARRING.

The Mayor of Worthing has called a public meeting to be held at the Connaught Hall, Worthing, on Thursday, November, 3rd, at 3 p.m., to consider what steps can be taken to preserve the three Thomas à Becket Cottages at West Tarring.



Thomas à Becket Cottages, West Tarring.

This property was recently put up to auction. Shortly before the sale it was ascertained that attempts to buy the cottages would be made by two

bidders, one with a view to demolishing them for the material which they contained, the other with a view to fitting them with modern plate-glass shop-windows, thus doubling their rental value.

It hardly seems credible that schemes of this sort could have been contemplated. Built about 1400 A.D., the cottages are of quite extraordinary beauty and interest. The oak mullions show marks where internal shutters were fixed, which could be closed at night and in bad weather, for the houses were erected before the days of glass or horn. The roofs are covered with Horsham slats, and these, together with the oak beams, are in perfect preservation. The interiors are also in an excellent state and the whole group forms a unique example of early fifteenth century architecture.

Thanks to the intervention of Mr. A. Mackenzie Ross, who resides near Worthing, aided by a substantial guarantee from the Society's Fund for the Preservation of Ancient Cottages, sufficient money was temporarily raised to buy in the property, which was secured for £950. It is hoped to raise £1000 which will render the houses permanently safe and enable the Society's Fund to recover part, at least, of the sum which it has advanced.

There can be no doubt about the great desirability of preserving these cottages. Tarring was an ancient town, filled—not many years ago—with beautiful buildings, including an historic monastery and an archbishop's palace. To-day nothing is left but a remnant of the palace and these three cottages. Gems of architecture and relics of historic interest, are they worth preserving? All who think so are earnestly invited to send a contribution to the West Tarring Cottages Fund, addressed to the Secretary, Royal Society of Arts, John Street, Adelphi, W.C.2.

NOTICES.

OPENING OF THE 174th SESSION.

The Opening Meeting of the 174th Session will be held at 8 p.m. on Wednesday, November 2nd, when the Inaugural Address will be delivered by SIR PHILIP MAGNUS, Bt., Chairman of the Council. The subject will be "The Royal Society of Arts: its Services to Trade and Training."

After the delivery of the Address, the Society's silver medals awarded for papers read last session will be presented.

PROGRAMME OF MEETINGS FOR THE 174th SESSION.

The programme containing a list of meetings for the 174th session, so far as these have already been arranged, has been posted to all Fellows.

PROCEEDINGS OF THE SOCIETY.

CANTOR LECTURES.

THE MEASUREMENT OF LIGHT.

By JOHN W. T. WALSH, M.A., D.Sc., F.Inst.P., A.M.I.E.E.,
Senior Assistant, National Physical Laboratory, and General Secretary,
International Commission on Illumination.

LECTURE II.—*Delivered May 2nd, 1927.*

MEASUREMENT ON THE PHOTOMETER BENCH.

In the first lecture of this series some of the earlier types of photometer were briefly described, and the principle of the method of candle-power measurement on the photometer bench was outlined. It will be remembered that the two sources to be compared were placed one on each side of the photometer head, and their positions were altered until a brightness match was obtained between the two sides of the photometer field. On the assumption that equality of brightness implied equality of illumination, the luminous intensities of the sources in the directions respectively facing the photometer were then related thus :—

$$I_1/d_1^2 = I_2/d_2^2$$

The first part of the present lecture will be devoted to a more detailed consideration of this method and of the apparatus required, including the modern forms of photometer head now generally employed.

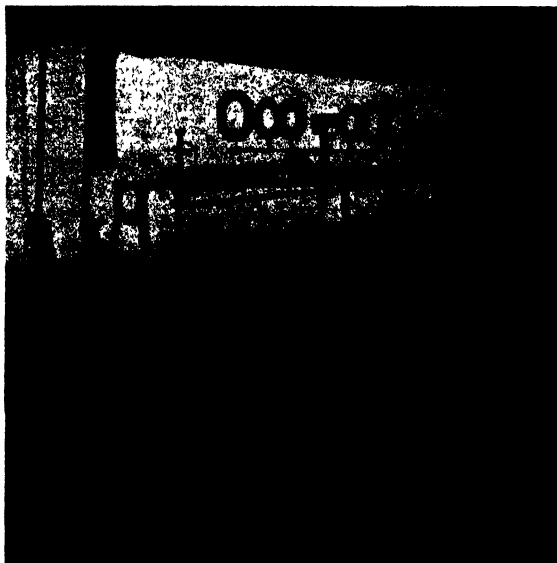


FIG. 10. The Photometer Bench.

A convenient type of bench is shown in Fig. 10. It consists essentially of two parallel steel bars, supported at a convenient distance apart by a rigid iron framework. Upon the bars run carriages which are used to support the light sources and the photometer head. These carriages run on spool-shaped wheels, so that they move easily on the bars. They are provided with means for raising or lowering the sources, and for enabling them to be turned about a vertical axis. Each carriage also bears a framework on which is engraved a line in the same vertical plane as the centre of the carriage pillar. This framework moves over a graduated scale attached to the bench framework. In this way the distances between the centres of any two carriages may readily be found at any time.

The process generally adopted for making candle-power measurements on the bench can best be described by reference to some particular form of head. It will therefore be convenient to give a brief account of a more accurate form of photometer than those mentioned in the last lecture.

It will be clear that if a sheet of matt white opaque paper be placed between two sources of light on a photometer bench, and if it can be assumed that both sides of the sheet of paper have exactly the same reflection factor, then when the two sides of the paper appear equally bright, the illuminations are equal and the ratio of the candle-powers of the two sources can therefore be found. In order that both sides of the paper may be seen simultaneously, inclined mirrors may be placed behind and on each side of the paper.

THE BUNSEN PHOTOMETER.

Such an arrangement, it is clear, may be used as a photometer, but it has the disadvantage that the two surfaces to be compared cannot be brought into contiguity. The great chemist Bunsen, therefore, hit upon a new criterion to assist the eye in making its judgment. If a spot in the centre of the paper be treated locally with oil or wax it will become translucent and each side of this spot will then owe its brightness for the most part to light from the lamp on the other side. Thus on each side of the screen so formed, the brightness of the opaque portion will be due to light from one lamp, that of the translucent portion to light from the other lamp. It will be seen at once that if the screen be moved slowly towards one lamp and away from the other, then on one side the opaque part will brighten and the translucent part darken, while on the other side the reverse will be the case. At some point between the lamps the contrast between the translucent spot and its background will appear to be the same on both sides and this is the criterion of equality adopted in Bunsen's photometer. It has been found that this criterion is a more sensitive one than that of simple brightness match and if the head be constructed with care it is capable of yielding very good results. It is, in fact, the progenitor of the most refined form of photometer in use to-day.

THE SUBSTITUTION METHOD.

With the Bunsen photometer head in mind it will be seen that the simplest method of making measurements on the bench is to move the head to and fro between the lamps until the point of balance is reached and then to apply the inverse square law. It will be noticed, however, that this method depends on the assumption, which was explicitly stated above, that the photometer screen is exactly the same on both sides as regards its reflection characteristics. This assumption, although plausible, is an extremely dangerous one and it is never made in accurate photometry.

Some other method is required in which exact symmetry of the photometer head is not essential. The method adopted is exactly analogous to that used for making accurate measurements of weight by means of a balance for which it is unsafe to assume exact equality of the arms. Even large errors in the balance can be compensated by placing the object to be weighed in one scale pan and balancing it with sand or similar material placed in the other pan. The object is then removed, and weights are placed in its stead to balance the sand. It is clear that in this way the error of the balance affects both the weights and the objects to be weighed by equal amounts, so that the true weight of the object is obtained.

In the photometric case, a lamp of constant but not necessarily known luminous intensity is placed in the carriage at one end of the bench, and this carriage is clasped by means of a rod to the carriage holding the photometer head, so that the two carriages move on the bench as one unit. It will be clear that in this way one side of the photometer field has a constant illumination. Other lamps can now be placed in turn at the other end of the bench, and the distances can be found at which the illuminations they produce at the photometer will balance this constant illumination. These illuminations must be equal to each other although, owing to asymmetry in the photometer head, they may not be equal to the constant illumination. If, then, the candle-powers of the lamps be I_1, I_2 , etc., and the distances at which a balance is obtained are d_1, d_2 , etc., it follows that $I_1/d_1^2 = I_2/d_2^2 = \text{etc.}$ Thus if one of the lamps be a substandard of known candle-power, the candle-powers of the other lamps may be found quite simply.

It is convenient in practice to arrange that I_1/d_1^2 shall have an even value, preferably a simple power of 10, and to put the lamps to be measured at the zero point of the bench. For instance, if the candle-power of the substandard be 18.3, the comparison lamp providing the constant illumination can be clamped at such a distance from the photometer that the balance point for the substandard is with the photometer carriage at a distance of $\sqrt{18.3}$, i.e. 4.28 feet from the zero, since this would give an illumination of exactly 1 foot-candle on the measuring side of the head. It will be seen that if this be done, the candle-power of any lamp can be found at once by simply squaring the bench reading of the photometer head at the point of balance.

It will naturally be understood that it is only possible to give a very brief outline of the method. There are numerous practical details which have to receive careful attention if accurate results are to be obtained. For instance one of the most frequent causes of error in photometry is the admission of stray light to the photometer. In all that has been said previously it has been tacitly assumed that the only light which reaches the photometer is that coming directly from the source on the bench. Unless precautions are taken, however, this light will illuminate the observer's face and other objects in the room, and some of this light may be reflected to the photometer. It is essential, therefore, that such sources of error should be eliminated by careful screening. This can be carried out very conveniently by having a series of thin blackened screens on each side of the photometer head. If they are placed at intervals along a rod attached to the photometer and arranged suitably, no light can reach the photometer surface except from within a narrow cone surrounding the lamp on the bench. A further screen, consisting of a piece of black velvet, should be placed behind this lamp, and as an additional precaution, black velvet curtains may be hung on each side of and over the bench.

Very little can be said as to the actual mode of working on the bench. For accurate measurement two observers work together. Each in turn makes five or ten settings on the bench, and these are noted by his companion. It has been found best that an observer should not take his own readings, partly owing to the possibility of his eye being disturbed should he, by accident, look at the lamp on the bench, and partly because he attempts, subconsciously, to correct any constant trend that his readings may happen to exhibit. When electric lamps are being measured, the careful control of the current passing through the filament is of the utmost importance. This will be realised at once when it is considered that, for a tungsten filament lamp, the rate of candle-power change is about 7 times as great as the rate of change in current, or about 3.7 times as great as the rate of change of applied voltage. This means that for accurate photometry the electrical measurements must be correct to at least 3 or 4 parts in ten thousand, so that indicating instruments are out of the question and a potentiometer control must be employed.

It must be realised, however, that a very great deal of photometry is carried out, in lamp factories and elsewhere, to an accuracy much less than that demanded for standardisation purposes. Often 2 or 3 per cent. in candle-power is quite adequate and then a number of simplifications can be introduced into the procedure. For instance, a single observer may be employed instead of two, and accurate indicating instruments may be used for the electrical measurements. Careful screening is still necessary, however, and the substitution method of photometry should always be employed.

THE LUMMER-BRODHUN HEAD.

So far the question of the best form of photometer head has been left an open one. The Bunsen head has been described briefly and an instrument of this

type is probably the best. The simple "grease-spot" has, however, been materially improved by the substitution of an ingenious optical device first described by Professor Swan of Edinburgh in 1859, but only put into the form of a practical photometer head by Lummer and Brodhun in 1889. The principle will be seen from Figure 11. ABC and DEF are right-angled glass prisms

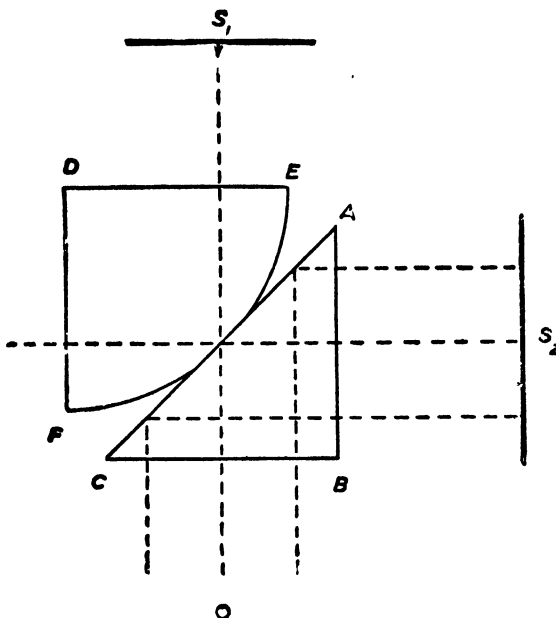


FIG. 11. The Principle of the Lummer-Brodhun Cube.

in one of which the principal surface is spherical, but with a small circular flat region at the centre. This presses against and makes optical contact with the flat surface of the other prism, while the outer parts of the surfaces are separated by air. It follows that light entering the prism system at the surface AB passes undeviated through the central portion in optical contact, while over the outer portion it is totally reflected, and emerges at BC. On the other hand, light entering DE is transmitted through the central portion and emerges at BC. Hence, if S_1 and S_2 be two comparison surfaces, the central part of S_1 is seen directly by an eye placed at O, while the outer part of S_2 is seen by total reflection at the surface AC, and the two together form a ring and disc field with a very fine and sharp line of demarcation if the prism DEF be skilfully constructed. For photometric purposes the cube and comparison surfaces are arranged as shown in Fig. 12. S is a sheet, about 4 mm. thick, of plaster of Paris, or some other white diffusing substance, held in a brass framework, the plaster surface being circular and about 52 mm. in diameter. The two sides of this disc are illuminated by the light from the two sources whose candle-powers are being compared, and the light from them is brought to the two

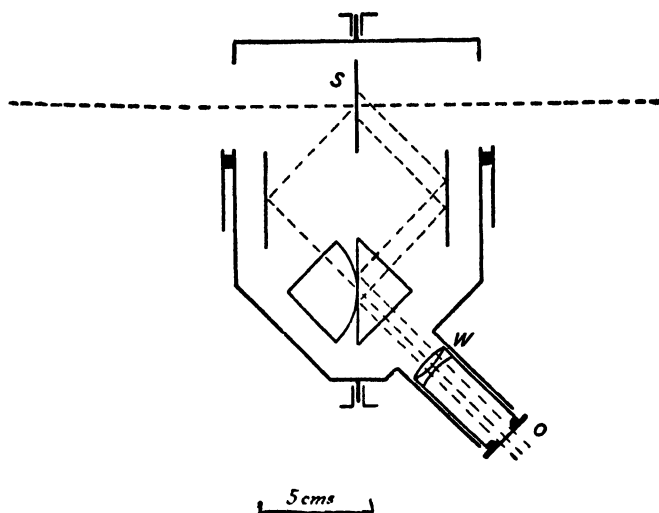


FIG. 12. The Lummer-Brodhun Head.

prisms of the cube by means of silvered glass mirrors or auxiliary total reflection prisms. The field of view seen by the eye at *O* consists of an annulus due to light from one side of *S* and a central spot due to light from the other side. The eyepiece is provided with a lens at *W*, so that the surface of the cube may be brought to a focus and the necessary sharpness of the boundary between the two parts of the field obtained. The plaster screen, mirrors, cube, and eyepiece are mounted rigidly inside a brass box provided with two openings by which the light from the sources may reach *S*. These windows are provided with brass cover-plates, which are used to close the windows when the photometer is not in use, and thus prevent, as far as possible, the entrance of dust. This, by settling on the glass surfaces, produces dark specks on the field which are very annoying to the eye when it is endeavouring to make a photometric balance. The interior of the photometer box is lined with black velvet or optical black in order to absorb stray light due to reflection from the glass surfaces.

It will be seen that although this form of photometer head is similar to the Bunsen grease-spot, it differs from it in two important respects. In the first place each half of the field receives light from one lamp only, whereas in the case of the translucent grease-spot a certain amount of light is reflected from the lamp which illuminates the opaque portion of the field, and this is mixed with the transmitted light. In this respect the optical system is distinctly better than the grease-spot. The dividing line, moreover, can be made much sharper than the edge of the grease-spot. In the second place, at the balance point the circular dividing line between the central patch and its background disappears in the case of the Lummer-Brodhun head, but not in the case of the Bunsen head. In the latter, as has been said already, the criterion is one

of equality of contrast and this is more sensitive than a simple equality-of-brightness judgment. In this respect, then, the Bunsen head is superior to the form of Lummer-Brodhun head just described, but, by a suitable modification of the latter, the advantages of both systems may be combined. The resulting head is known as the Lummer-Brodhun contrast head, and is shown in Figure 13.

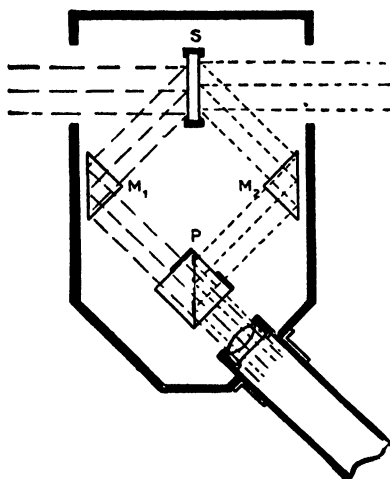


FIG. 13. The Contrast Head.

Two prisms are used, as before, but the faces of both are flat and that of one prism is sand blasted or etched with the pattern shown shaded in Figure 14. The result is that when the prisms are pressed together, either with or without

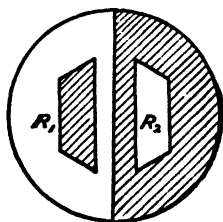


FIG. 14. Field of View of the Contrast Head.

balsam, so that the smooth parts are in optical contact, the light passes straight on in the region shown unshaded in Figure 14, while the light entering from the left is totally reflected over the region shown shaded in that figure. It follows that if the cube be mounted as in Figure 13, the brightness of the unshaded region is due to the left-hand side of S, while the brightness of the shaded region is due to the right-hand side of S. If thin sheets of glass G_1 , G_2 be added as in Figure 13, then, owing to reflection at the two additional glass surfaces thus introduced, the brightness of the trapezoidal patch R_1 in Figure 14 will be

about 8 per cent. less than that of the background to R_2 , while the brightness of R_2 will similarly be 8 per cent. less than that of the background to R_1 . Thus at the position of balance the contrast between trapezoid and background will be 8 per cent. on both sides of the field of view and this contrast will be increased on one side and diminished on the other as the photometer is moved away from the position of balance. Thus the criterion is equality of contrast.

There is one other form of photometer which may, perhaps, be mentioned. This is the Joly block which consists of two pieces of opal glass, or some other convenient translucent material, separated by a piece of tinfoil. The lamps to be compared illuminate the two sides of the composite block and the criterion of equality is equal brightness of the edges of the two blocks. The head is a sensitive one, and its chief disadvantage is the uncertainty of the position in the blocks from which measurements should be made.

No mention has been made yet of a very important class of photometer designed especially to avoid the difficulties introduced when the two lights to be compared differ markedly in colour. These are generally known as flicker photometers and will be described in the next lecture when the subject of heterochromatic photometry is under consideration.

THE MEASUREMENT OF LUMINOUS FLUX.

While it is true that the measurement of luminous intensity is the most fundamental of photometric measurements, it is also true that the measurement of luminous flux is nowadays the most important from the point of view of the rating of light sources.

It is clear from what was said in the last lecture that the luminous flux output of a source may be obtained by measuring its candle-power in a large number of directions uniformly disposed in space. This is a long and tedious process however, and it is fortunate that in the case of certain sources, it is only necessary to make measurements in a limited number of directions in a single plane. The light from a tungsten filament vacuum lamp of ordinary filament form, for instance, is distributed fairly symmetrically about the axis of the lamp. Moreover, this lamp can be spun about its axis while the photometric measurements are being made, so that the figure of candle-power obtained at any given angle with the axis is, in reality, the mean value of a cone.

Now it is not difficult to show that, for a source such as this, in which the distribution of the light is not unduly irregular, the mean spherical candle-power may be obtained by taking the arithmetic mean of measurements made in a limited number, say twenty, specified directions. The figure thus obtained, when multiplied by 12.6, gives the flux output of the lamps in lumens. Alternatively, it has been found that, to a fairly close approximation, the mean spherical candle-power of such a lamp is equal to its mean horizontal candle-power multiplied by 0.785.

Thus it is not a difficult matter to obtain the luminous flux output from a lamp of this kind, and all that remains to be done is to find a method for measuring the flux output from more irregular sources by comparison with this known source.

The method which is almost universally adopted to-day is that devised by R. Ulbricht in 1900 and based on work by W. E. Sumpner in this country in 1892. Sumpner showed theoretically that if a source of light be placed inside a hollow sphere covered internally with some perfectly diffusing surface paint, the same amount of light is received at any part of the sphere surface by reflection from all the other parts. The light received directly from the source naturally differs according to the candle-power distribution of the source, but the light which has been reflected once or more from the walls of the sphere is distributed perfectly uniformly no matter how unsymmetrical the original distribution from the source itself may be.

It will be clear that this principle leads at once to a practical method of comparing the total flux from two sources. All that is necessary is to place them in turn within a sphere of the kind described, to screen a small portion of the sphere surface from direct light and to measure the illumination of this screened area in the two cases. The ratio of the illuminations will then be strictly equal to the ratio of the flux outputs of the sources.

While this method is simplicity itself in theory, practical limitations, as usual, introduce difficulties and uncertainties which have to be studied closely before reliance can be placed on the accuracy of the results obtained in any particular case. In the first place, Sumpner's theory assumes that the sphere is completely empty so that there is no interference with the light as it is reflected to and fro from one part of the sphere to another. It is clear that the source itself, being of finite dimensions, produces a certain amount of disturbance. Further, the necessity for screening a part of the sphere surface from direct light means that some form of opaque screen must be introduced, and the presence of this screen is a further violation of the ideal conditions. In the second place, it was mentioned that the sphere surface should be perfectly diffusing. No such surface is known and even the best approximation shows very marked departures from the theoretical distribution when the light reaches it very obliquely.

Lack of perfect diffusion can only be compensated by having the greatest possible amount of inter-reflection between different parts of the wall. In other words, the sphere surface, in addition to being as matt as possible, should have as high a reflection factor as possible.

The interference due to the presence of the lamp and its supports and of the screen can only be reduced by having the sphere as large as possible in comparison with these objects. It has been suggested that the area of the sphere should be at least 100 times that of a sheet of material stretched tightly over the lamp and its accessories. Further, any surfaces which do not act as

secondary sources of light, such as the upper side of an opaque reflector, should be whitened so that the reflected flux is absorbed as little as possible.

For the measurement of ordinary electric lamps or similar sources a sphere of 1 metre diameter is convenient. For measuring the flux output from large fittings, such as industrial or domestic lighting fittings, street lanterns and the like, a much larger sphere is necessary, and a 10-foot diameter sphere has recently been erected at the National Physical Laboratory.

Various methods have been employed for measuring the reflected flux reaching the screened area of the sphere surface. It is clearly not necessary that this measurement should be absolute, since only a ratio is involved. Any method which gives a measure proportional to the reflected flux is therefore admissible. The most common is to have an opening in the sphere and to cover this with a window of opal glass or some other translucent material. The brightness of this window as viewed from outside the sphere is then measured, either by means of some form of portable photometer, such as that to be described presently, or by means of a photometer head and comparison lamp moving on a bench attached to the sphere.

If the latter method be used, it is generally found necessary to have the photometer head close to the sphere window in order to obtain sufficient brightness of the comparison field. Since the linear dimensions of the window are then generally large compared with the distance between it and the photometer, the inverse square law can no longer apply, and it is necessary to keep the distance between the photometer head and the window fixed during the measurements. The photometric match is obtained by moving the comparison lamp to and fro on the bench.

The difficulty of constructing a sphere has led to the adoption in some laboratories of a cube as a sufficiently near approximation for work of moderate accuracy. A closer approximation to the spherical form may be obtained by blocking out the corners of the cube with triangular pieces, so as to form a fourteen-sided polyhedron. The chief objection to these non-spherical forms is that it is not possible to subject them to any form of mathematical treatment such as is possible in the case of the sphere. Two things, however, are certain. When a cube is used, the light source should be placed in the centre with its axis of symmetry perpendicular to the line joining it to the window, the window being assumed to occupy the centre of one face of the cube. Secondly, it is clear that if the light distribution from the sources to be compared are exactly the same, the form of the enclosure employed will be immaterial. So long, therefore, as the distributions do not differ too much, a cube should be capable of giving quite satisfactory results.

THE MEASUREMENT OF ILLUMINATION.

The third photometric measurement of importance is that of illumination. Modern developments in the practice of illuminating engineering have brought

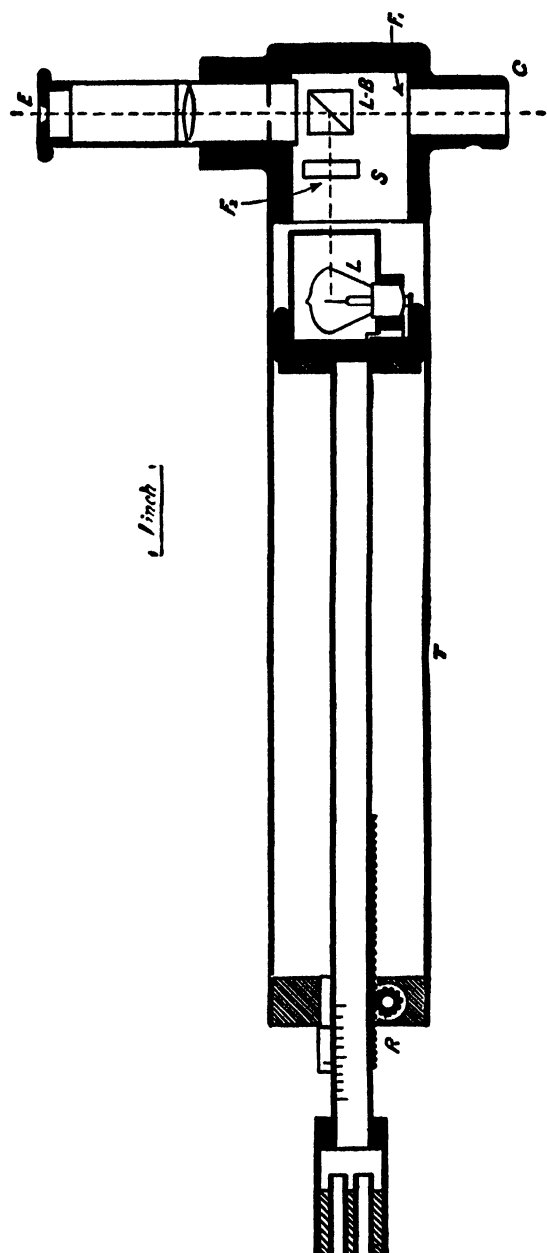


FIG. 15. The Macbeth Illuminometer.

this type of measurement into great prominence during the last decade, and there are now many different instruments commonly employed for the purpose. In fact it is probably correct to say that the measurement of illumination is

the best known operation, and the illumination photometer the most common photometric instrument, at the present time.

Every illumination photometer consists of three essential parts. These are (i) a test plate or standard surface placed at the spot at which the illumination is to be measured and generally, but not always, detached from the remainder of the instrument, (ii) a surface inside the instrument, which is illuminated by a small battery lamp in such a way that its brightness can be varied at will by the observer, and (iii) some form of comparison device for comparing the brightness of the internal surface with that of the external test plate.

A description of all the different types which have been devised at various times would be tedious and would serve no useful purpose, and it will be sufficient to give a brief account of the general principles of three typical instruments which exhibit certain fundamental differences.

The most natural form of instrument is one in which the inverse square law is used to obtain the necessary variable brightness. An instrument of this type is the Macbeth Illuminometer, shown in Figure 15. The opal glass comparison surface *S* is illuminated by the lamp *L*, which, in its diaphragm enclosure, may be moved along the tube *T* by means of a rack and pinion *R*. The brightness of *S* is compared with that of the external test surface by means of the small Lummer-Brodhun cube *L-B*, the eye being placed at *E*. An inverse square scale is attached to the rod by means of which *L* is moved, and the constant of this scale is adjusted to unity by previous calibration with a known illumination on the test surface. It is clear that this calibration may be carried out quite conveniently on the ordinary photometer bench. The test surface is set up at the zero of the bench and a substandard of known candle-power is placed at such a distance from it that the illumination has any convenient value, say one foot-candle. The same method may be used for calibrating the scales of the other types of portable photometer to be described later. The only difference is that, when the scale of the instrument does not follow a definite theoretical law, a number of different values of illumination of the test surface are required so as to give sufficient points for a scale to be constructed empirically.

An instrument in which the inverse square law is not employed is the Holophane Lumeter, shown in Figure 16. The lamp *L* is enclosed in a whitened box of shallow cylindrical form. This box is provided with a window of diffusing glass *W*, the light from which illuminates the opaque outer parts of the comparison screen *S*. The eye at *E* views the test surface *T* through the central transparent part of *S*, and the two parts of the field are adjusted to equality by altering the exposed area of *W*. This is achieved by means of a cylindrical shutter which can be rotated about the lamp enclosure by means of the handle *H*. The shutter is provided with an opening of the form shown in the figure. It will be clear that if *W* is uniformly bright, the scale of the instrument will consist of three parts, one corresponding to each of the three breadths of opening, the scale being even within each part.

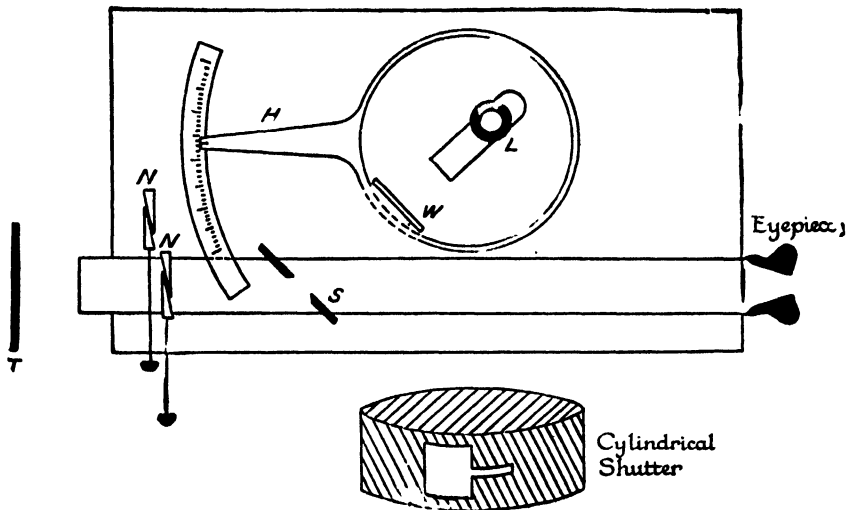


FIG. 16. The Holophane Lumeter.

In both the Macbeth Illuminometer and the Lumeter, the scale of the instrument may be extended by the provision of neutral glass screens with transmission factors of one-tenth. If these are inserted between the test surface and the eye, the scale is extended upwards, the instrument reading having to be multiplied by 10 or 100 according as one or both of these screens is inserted. If the screens are inserted between the internal lamp and the comparison surface, the instrument reading must be divided by the appropriate factor.

The lamp is supplied from some form of portable battery, either a dry battery or, preferably, an accumulator. An adjustable rheostat and a voltmeter or ammeter are provided for adjusting the current through the lamp to the value at which the instrument was calibrated. This adjustment has to be made with the greatest possible care since, owing to the characteristics of the small battery lamps which have to be used, an error of 1 per cent. in the current setting may mean an error of as much as 10 per cent. in the readings.

There are other precautions which have to be taken when making measurements with illumination photometers. It will be seen, for instance, that the accuracy of the measurement depends on the constancy of the reflection factor of the test surface. Clearly it is desirable that, as far as possible, the brightness of this surface should depend only on the illumination and not at all on the angle at which the light reaches the surface or on the direction from which it is viewed. In other words, an ideal test surface would be perfectly diffusing. Unfortunately as has been said already, no such surface exists in practice, and all that can be done is to use the best approximation available, due regard being paid to the other requirements of colourlessness, permanence and durability, and ease of cleaning or renewal. The two surfaces most commonly employed are opaque

white celluloid which has been rendered matt by sandblasting, and dense opal glass etched or ground on its upper surface.

The error due to lack of perfect diffusion may be reduced by ensuring that the surface is always viewed at the same angle, and it has been found that for these surfaces an angle of between 20 and 30 degrees with the normal to the surface is the best.

Frequently it is desired to measure the illumination of the working plane, generally assumed horizontal. Sometimes the lamps illuminating certain parts of this plane are at considerable distances, so that the light is incident very obliquely. It is then necessary to level the test surface accurately since a tilt of 2 or 3 degrees may in such circumstances produce quite a large error. An extreme case of this kind is met with in street lighting where the light reaching the street mid-way between lamps may make an angle of as little as 6 or 8 degrees with the horizontal. In such cases it is best to tilt the surface so that it is perpendicular to the light rays. The measured illumination is then multiplied by the cosine of the angle of tilt in order to obtain the illumination of a horizontal surface at the point. A special device has been designed for use with the Lumeter to facilitate this type of measurement. A sighting device enables the test surface to be set accurately perpendicular to the light rays, and an angular scale then gives the angle of tilt required for the calculation,

A somewhat different form of illumination photometer suitable for more approximate work and especially for demonstration purposes is that shown in

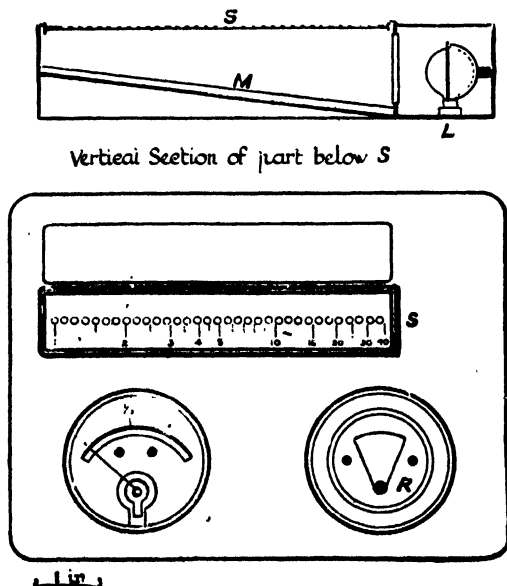


FIG. 17. The Foot-Candle Meter.

Figure 17. The lamp L illuminates the under side of a long screen S, partly by direct light and partly by reflection from a strip of mirror M, which is tilted as required when the instrument is re-adjusted from time to time. S consists of a strip of opaque white paper with a row of Bunsen spots in it. Since the brightness of these spots decreases progressively from the end of the screen which is nearest to the lamp, any given illumination of the screen from above will cause one of the spots to match its surroundings in brightness, while all those on the right appear bright, and those on the left appear dark. An empirically graduated scale printed on the screen enables the illumination to be read directly in foot-candles. The lamp is supplied with current from a dry battery, the rheostat R being turned until the correct indication is given by the voltmeter V. To extend the range of the instrument downwards, R may be increased until the voltmeter needle indicates a division marked $1/10$. The candle-power of the lamp is then one-tenth of its normal value, and the instrument therefore measures from 0.1 to 4 foot-candles, instead of from 1 to 40, as when the full current is passing through the lamp.

It has been said already that there are many other types of illumination photometers now in use, but these examples will serve to show the manner in which illumination may be measured directly in any accessible position.

A difficulty which has not been mentioned so far is that due to the colour difference between the light given by most modern light sources and that given by the battery lamp in the instrument. This is sufficiently great to introduce serious errors in the measurement unless some means are adopted to eliminate, or at least to reduce it. The simplest method is to insert a slightly bluish medium, either glass or gelatine, between the lamp and the comparison surface. If this medium be suitably chosen, both as regards colour and permanence, and if the instrument be calibrated with it in place, no difficulty due to colour difference arises when measurements are being made "in the field."

There is, however, one important class of illumination measurement which requires special treatment, *viz.* the measurement of daylight either natural or artificial. The colour difference involved in this measurement must be compensated by the use of a special blue filter on the lamp side of the comparison field, or a special yellow filter between this field and the external test surface. The chief objection to the former scheme is that it seriously reduces the candle-power available from the lamp, and therefore the upper range of the instrument. The objection to the yellow filter is that its transmission factor depends on the colour composition of the particular kind of "daylight" being measured, and it may be very different in the extreme cases of noon sunlight and light from a clear blue sky. Nevertheless, the yellow filter is the one generally adopted in practice at the present time.

MEASUREMENT OF REFLECTION FACTOR.

An illumination photometer, such as the Macbeth or the Lumeter, may also be used for measuring the reflection factors of surfaces. It is clear that if two

surfaces are equally illuminated, their brightnesses are proportional to their reflection factors. If, therefore, any surface be substituted for the test surface of an illumination photometer the reading obtained will bear to the actual illumination the same ratio that the reflection factor of the surface bears to the reflection factor of the test surface.

For example, suppose a reading of 0.3 foot-candle be obtained when the instrument is directed towards a certain portion of the wall of a room, while the illumination of this portion, measured as usual, is 0.9 foot-candle. Then the reflection factor of the wall surface is one-third that of the test surface. If the latter is known to be 90 per cent., it follows that the reflection factor of the wall is 30 per cent.

NOTES ON BOOKS.

CO-OPERATIVE INDUSTRIAL RESEARCH, with a Preface by the Rt. Hon. The Earl of Balfour, K.G., O.M., F.R.S. London: H.M. Stationery Office. Ninepence net.

One result of the attention devoted towards the end of the War to the problem of "reconstruction" was the provision by the Government, through the Department of Scientific and Industrial Research, of a fund of a million sterling, to "encourage the industries of the country to undertake scientific research." As Lord Balfour remarks in his Preface, "it is when trade is bad and foreign competition is most severe that researches of the kind contemplated are most required; but it is precisely at times like these that a manufacturer is least able and least willing to undertake them." Such conditions we have experienced on an almost unprecedented scale since 1920, and it may well be that this timely action on the part of the Government has been a real factor in any improvement that has since taken place.

Assistance rendered, so far as it is the subject of this pamphlet, has taken the form of direct financial help in the creation and maintenance of Research Associations in the various industries concerned. As a matter of convenient machinery, these Associations are registered as limited companies, though of course they distribute no dividends. The Department has been quite alive to the dangers of State control when applied to activities of this kind, and in most cases a generous measure of autonomy is possessed by the Associations.

The main object of the present publication is to give a rough idea of the degree of success which has been attained by the Associations in actual practice, and a summary of the work carried out in each industry has therefore been provided. The facts related in these summaries are both interesting and instructive, and should go far to convince the most hardened individualist of the merits of the scheme. In addition, the conditions on which assistance is afforded are briefly set forth.

MEETINGS OF THE SOCIETY BEFORE CHRISTMAS.

ORDINARY MEETINGS.

Wednesday evenings at 8 o'clock (unless otherwise announced).

NOVEMBER 2.—Opening Meeting of the One-hundred-and-seventy-fourth Session
Inaugural Address by SIR PHILIP MAGNUS, Bt., Chairman of the Council of the Society, on "The Royal Society of Arts: its services to Trade and Training."

NOVEMBER 9.—MERVYN O'GORMAN, C.B., D.Sc., M.Inst.C.E., "Road Traffic Problems of the Pedestrian." The Hon. Sir ARTHUR STANLEY, G.B.E., C.B., M.V.O., LL.D., Chairman, Royal Automobile Club, will preside.

NOVEMBER 16.—PROFESSOR LEONARD HILL, M.B., F.R.S., Hon. A.R.I.B.A., "Overcrowding in Public Conveyances." THE RIGHT HON. LORD DAWSON OF PENN, G.C.V.O., K.C.B., K.C.M.G., M.D., D.C.L., will preside.

NOVEMBER 23.—T. HEDLEY BARRY, "Malayan Resins." A. F. SUTER, Esq., will preside.

NOVEMBER 30.—PROFESSOR HENRY E. ARMSTRONG, LL.D., Ph.D., F.R.S., "Marcellin Berthelot and Synthetic Chemistry." His EXCELLENCY THE FRENCH AMBASSADOR will preside.

DECEMBER 7.—S. J. DULY, M.A., Head of Department of Commercial Products, City of London College, Mitchell Student for 1925-6, "The Damage to Cargo due to 'Ship's Sweat.'"

DECEMBER 14.—MAJOR RAYMOND G. H. CLEMENTS, M.C., M.Inst.C.E., "Road Surfaces."

INDIAN SECTION.

Friday afternoons, at 4.30 o'clock.

NOVEMBER 11.—M. M. S. GUBBAY, C.S.I., C.I.E., "Indigenous Indian Banking." SIR HENRY STRAKOSCH, G.B.E., will preside.

DECEMBER 9.—SIR DAVID T. CHADWICK, C.S.I., C.I.E., "The Indian Tariff Board." SIR CAMPBELL RHODES, C.B.E., will preside.

CANTOR LECTURES.

Monday evenings, at 8 o'clock.

PROFESSOR H. C. H. CARPENTER, M.A., A.R.S.M., F.R.S., "Alloy Steels, their Manufacture, Properties, and Uses." Four Lectures. November 14, 21, 28, and December 5.

LECTURE I.—Definition. Historical Introduction. Statistics of production. Principal alloying metals used. Ternary, quaternary and more complex steels. Importance of heat-treatment. The effect of alloying metals on the inclusions of steels. Methods of classifying alloy steels by: (1) Dilatation curves, (2) Structural diagrams.

LECTURE II.—Tungsten steels. Special properties and uses. Magnet steels. Tungsten-cobalt-chromium magnet steels. Chromium steels. Hardness. Resistance to staining and corrosion. Manganese steels. Manufacture and properties. Hadfield's manganese steel. Resistance to wear and abrasion. Castings. Heat treatment. Hot-worked manganese steel. Uses.

LECTURE III.—Nickel steels and nickel-chromium steels. Their use for structural purposes. Wide field of usefulness. Armour plates and projectiles. Heat-treatment. Temper brittleness. Effect of molybdenum in mitigating this. Silicon steels. Structural and electrical uses.

LECTURE IV.—Chromium-vanadium steels. Use in automobile industry. Tungsten-chromium and tungsten-chromium-vanadium steels. High-speed tool steels. Their manufacture and characteristic properties. Hardening treatments. Red hardness. Theory of high-speed steels. Heat-resisting steels. Value of chromium. Chromium-nickel-silicon and chromium-nickel-tungsten steels.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

- MONDAY, OCTOBER 31.** Actuaries, Institute of, Staple Inn Hall, Holborn, W.C. 5 p.m. Sir Joseph Burn, Presidential Address on "The Eighth International Congress of Actuaries."
Farmers' Club, at the Surveyors' Institution, Great George Street, S.W. 4 p.m. Mr. A. J. Hosier, "Open Air Dairying."
Philologie, Sciences et Beaux-Arts, Société Internationale de, 8, Tavistock Street, W.C. 3.30 p.m. Dr. Mirza M. H. Taimuri, "Culture Islamique."
University of London, at King's College, Strand, W.C. 5.30 p.m. Prof. Dr. Ernest Cassirer, "Die Entwicklung der Modernen Wissenschaft und die Grundprinzipien des Kritischen Idealismus" (in German). (Lecture I.)
- TUESDAY, NOVEMBER 1.** Academy of Arts, Royal, Burlington House, W. 4.30 p.m. Prof. Dr. Arthur Thomson, "Anatomy: the Essential Features of the Face, Head and Neck." (Part I.)
Anthropological Institute, 52, Upper Bedford Place, W.C. 8.30 p.m. "Excavation of a Moustrian Site at Devil's Tower, Gibraltar." Miss Dorothy Garrod (Archæology and Palæontology); Mr. L. H. D. Buxton (Human Remains); Prof. Elliot Smith (The Endocranial Cast).
Civil Engineers, Institution of, Great George Street, S.W. 6 p.m. Mr. Ernest F. C. Trench, Presidential Address.
Electrical Engineers, Institution of, at the Hotel Metropole, Leeds. 7.15 p.m. Mr. J. E. Storr, Chairman's Address.
At the Midland Hotel, Manchester. 7 p.m. Mr. A. B. Mallinson, Chairman's Address.
Metals, Institute of, at Armstrong College, Newcastle-on-Tyne. 7.30 p.m. Mr. G. Burns, "Mechanical Properties of Metals at High Temperatures."
North-East Coast Institution of Engineers and Shipbuilders, at the Cleveland Scientific and Technical Institution, Middlesbrough. 7.30 p.m. Mr. W. G. Richards, Chairman's Address.
Photographic Society, 35, Russell Square, W.C. 7 p.m. Mr. Bertram Cox, "Some Negatives and why I made them."
Physiology, London College of, 8, Tavistock Street, W.C. 8.15 p.m. Mr. Frank W. Britton, "Ionisation and other Ethereal Phenomena."
Royal Institution, 21, Albemarle Street, W. 5.15 p.m. Sir J. H. Parsons, "Light and Sight." (Lecture I.)
Transport, Institute of, at the University, Bristol. 5.30 p.m. Mr. F. H. Wort, "The Early Use of Petrol Vehicles for Army Manœuvres."
Zoological Society, Regent's Park, N.W. 5.30 p.m. Scientific Business Meeting.
- WEDNESDAY, NOVEMBER 2.** Analysts, Society of Public, at the Institute of Pathology and Research, St. Mary's Hospital, Paddington, W. 8.15 p.m. Sir William Wilcox, "The Biological Tests for Blood." Dr. G. Roche Lynch, O.B.E., "The Technique of the Precipitin Test and its Forensic Value." Dr. F. C. Martley, M.A., "The Use of the Blood Grouping Reactions in Forensic Investigation."
Archæological Institute, at Burlington House, W. 5 p.m. Mr. G. H. Jack, "The Romano-British Town of Magna (Kenchester)."
Automobile Engineers, Institution of, at the Queen's Hotel, Birmingham. 7 p.m. Major E. G. Beaumont, "The Influence of the Automobile User upon the Automobile Engineer."
Electrical Engineers, Institution of, Savoy Place, W.C. 6 p.m. Lieut.-Colonel A. G. Lee (Chairman of the Wireless Section), Inaugural Address.
At the Cleveland Technical Institute, Middlesbrough. 7 p.m.
Elizabethan Society, at King's College, Strand, W.C. 8 p.m. Mr. S. R. Littlewood, "An Evening with Coryate."
Geological Society, Burlington House, W. 5.30 p.m. Dr. J. A. Douglas and Mr. W. J. Arkell, "The Stratigraphical Distribution of the Cornbrash: I.—The South-Western Area."
Heating and Ventilating Engineers, at Caxton Hall, Westminster, S.W. 7 p.m. Mr. W. C. Freeman,
- "The Production and Modern Applications of Dissolved Acetylene."
Overhead Lines Association, at the Royal Society of Arts, Adelphi, W.C. 5.30 p.m.
Public Health, Royal Institute of, 37, Russell Square, W.C. 4 p.m. Sir Henry Gauvain, "Tuberculosis as a Problem of Childhood."
University of London, at Imperial College of Science South Kensington, S.W. 5.30 p.m. Lieut.-General Sir A. A. Montgomery-Massingberd, "The Role of the Army in Imperial Defence."
At King's College, Strand, W.C. 5.30 p.m. Prof. Dr. Ernest Cassirer, "Die Entwicklung der Modernen Wissenschaft und die Grundprinzipien des Kritischen Idealismus" (in German). (Lecture II.)
At University College, Gower Street, W.C. 5.30 p.m. Major Cyril Davenport, "Nineteenth Century Methods of Book Illustration."
- THURSDAY, NOVEMBER 3.** Automobile Engineers, Institution of, at the Royal Society of Arts, Adelphi, W.C. 7.45 p.m. Mr. H. B. Taylor, "High-Speed Compression-Ignition Engine Research" (Joint meeting of the Institution of Automobile Engineers and the Royal Aeronautical Society).
Chemical Society, Burlington House, W. 8 p.m. Mr. F. G. Mann, "The Complex Salts of Nickel with Various Aliphatic Diamines." Messrs. T. K. Walker, V. Subramaniam and F. Challenger, "The Mechanism of the Formation of Citric and Oxalic Acids from Sugars by *Aspergillus Niger*." Messrs. W. R. Bucknall and W. Wardlaw, "The Complex Cyanides of Molybdenum." Messrs. F. B. Garner and S. Sugden, "The Parachor and Chemical Constitution. Part VI. Some Cases of Supposed Ring-chain Tautomerism."
Child-Study Society, at 90, Buckingham Palace Road, S.W. 6 p.m. Miss Hardley Hall, "Child Education in Vienna."
Electrical Engineers, Institution of, Savoy Place, W.C. 6 p.m. Messrs. A. H. Law and J. P. Chittenden, "Higher Steam Pressures and their Application to the Steam Turbine."
L.C.C. Geffrey Museum, Kingsland Road, Shoreditch, E. 7.30 p.m. Mr. Walter H. Godfrey, "The English Staircase."
Linnean Society, Burlington House, W. 5 p.m.
Mechanical Engineers, Institution of, Storey's Gate, S.W., at Glasgow. Mr. G. K. Nichol, "Surface Condensing Plant."
Royal Institution, 21, Albemarle Street, W. 5.15 p.m. Mr. H. Clifford Smith, "Furniture of the Mediaeval House."
University of London, at the Royal Society of Medicine, 1, Wimpole Street, W. 5 p.m. Mr. Lionel Colledge, "The present position of Laryngectomy for Cancer of the Larynx."
At the Victoria and Albert Museum, South Kensington, S.W. 5.30 p.m. Mr. B. J. Fletcher, "Silver-myths' Work, Old and New."
- FRIDAY, NOVEMBER 4.** Academy of Arts, Royal, Burlington House, W. 4.30 p.m. Prof. Dr. Arthur Thomson, "Anatomy: the Essential Features of the Face, Head and Neck." (Part II.)
Mechanical Engineers, Institution of, Storey's Gate, S.W. 6 p.m. Sir William H. Bragg, "Application of X-Rays to the Study of the Crystalline Structure of Materials" (Thomas Hawksley Lecture).
North-East Coast Institution of Engineers and Shipbuilders, at the Mining Institute, Newcastle upon-Tyne. 6 p.m. Dr. J. Bruhn, "The Safety of Ships against Capsizing."
Photographic Society, 35, Russell Square, W.C. 7 p.m. Informal Meeting of Pictorial Group (W. L. Shand).
Transport, Institute of, at the Midland Hotel, Manchester. 6.30 p.m. Meeting for Graduates and Students.
At Leeds. Sir John E. Eaglesome, "Road and Rail Traction—a Comparison."
University of London, at King's College, Strand, W.C. 5.30 p.m. Prof. Dr. Ernest Cassirer, "Die Entwicklung der Modernen Wissenschaft und die Grundprinzipien des Kritischen Idealismus" (in German). (Lecture III.)
- SATURDAY, NOVEMBER 5.** L.C.C. Horniman Museum, Forest Hill, S.E. 3.30 p.m. Mr. H. Harcourt, "Indian Pictures and Problems."
Royal Institution, 21, Albemarle Street, W. 3 p.m. Mr. E. Cammaerts, "Main Features of Modern English Literature."

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FRIDAY, NOVEMBER 4th, 1927.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2.)

NOTICE.

NEXT WEEK.

WEDNESDAY, November 9th, at 8 p.m. (Ordinary Meeting). MERVYN O'GORMAN, C.B., D.Sc., M.Inst., C.E., "Road Traffic Problems of the Pedestrian." THE HON. SIR ARTHUR STANLEY, G.B.E., C.B., M.V.O., LL.D., Chairman, Royal Automobile Club, will preside.

FRIDAY, November 11th, at 4.30 p.m. (Indian Section). M. M. S. GUBBAY, C.S.I., C.I.E., General Manager, P. & O. Banking Corporation, Ltd., "Indigenous Indian Banking." Sir HENRY STRAKOSCH, G.B.E., will preside. Tea will be served in the Library at 4 o'clock before the meeting.

ROYAL SOCIETY OF ARTS.

CANTOR LECTURES.

THE MEASUREMENT OF LIGHT.

By JOHN W. T. WALSH, M.A., D.Sc., F.Inst.P., A.M.I.E.E.,
Senior Assistant, National Physical Laboratory, and General Secretary,
International Commission on Illumination.

LECTURE III.—*Delivered May 9th, 1927.*

HETEROCHROMATIC PHOTOMETRY.

In the previous lectures of this series only passing mention was made of what is, in reality, the greatest difficulty in photometric measurement, *viz.*, a difference of colour between the lights to be compared. All the sources of light

in general use differ in the colour of the light which they emit. The light from an electric lamp becomes whiter, *i.e.*, the proportion of blue becomes higher as the efficiency is increased, so that the modern gas-filled lamp, for example, is whiter than the tungsten filament vacuum lamp, which, in its turn, is whiter than the carbon filament lamp. Whitest of all is the arc lamp with plain carbon electrodes. The Welsbach mantle, again, has its own peculiar colour, which is slightly greenish compared with the electric lamp.

Now all these sources, and many others, have to be measured in terms of the international candle which, as has been said, is maintained by means of carbon filament lamps. It follows that at some stage in the measurements the really large colour differences involved have to be bridged with as little loss of accuracy as possible.

It has sometimes been stated that the presence of a colour difference must fundamentally invalidate any photometric measurement, just as it is manifestly impossible to express equivalence between a given number of sheep and any number of cows. The analogy, however, is false in that the comparison is one of a specific quality of the lights, and not of the lights themselves. It is perfectly possible to express the weight of a given number of sheep in terms of the weight of a cow, and in photometry what is desired is to express the *intensity* of one light in terms of that of another. The difficulty of the photometric problem arises from the fact that the eye finds it difficult to compare intensities in the presence of a colour difference. As Bouguer pointed out, however, there is always a point at which one of the two lights is certainly more intense than the other, and another point at which this light appears the more feeble of the two. It remains, then, to reduce as much as possible the distance between these points so that the estimation of the true point of equality shall be as precise as possible.

Of the various methods which have been proposed and used at different times, the most important in modern photometry is the flicker method. A photometer head constructed on this principle is so designed that the two parts of the comparison field are presented to the eye, not side by side, but one after the other in rapid alternation. When the speed of alternation is low the field is observed to flicker whatever be the relative intensities of the two lights, but as the speed is raised the flicker gradually decreases until finally it can be made to disappear at one position of the head between the light sources. If the speed be maintained at this critical value, a slight movement of the photometer head or of either source from the position of balance causes a flicker to appear. The critical speed depends on the colour difference between the lights, being naturally higher the larger the difference. Any increase in speed beyond that just necessary to remove flicker at the point of balance results in a decrease of sensitivity. It is therefore a first essential of any flicker photometer that it should be provided with an easy and rapid speed adjustment.

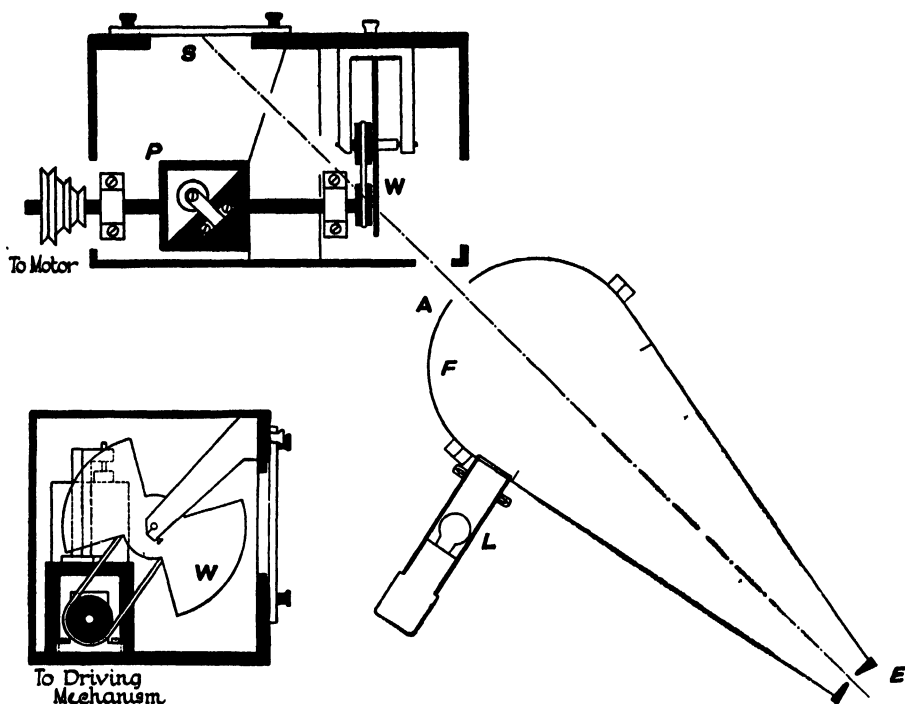


FIG. 18. The Guild Flicker Photometer.

Many different types of flicker photometer have been developed. Of the more accurate, the one due to Mr. Guild, and shown in Figure 18, is, perhaps, the simplest in principle, and will serve to illustrate the method. *S* is a white surface of magnesium oxide illuminated, by way of the total reflection prism *P*, by the light from one of the sources to be compared. *W* is a Whitman disc, which can be rotated at any desired speed about a horizontal axis. Its surface is covered with magnesium oxide, and is illuminated by the other source of light so that, when viewed by the eye at *E*, the field of view seen through the small aperture *A* is alternately occupied by *W* and by *S*. *A* is of such a size as to subtend an angle of 2° at *E*. It is cut with a sharp (back-bevelled) edge in a concave surface *F*, which is also covered with magnesium oxide and is evenly illuminated by the small lamp *L*, the light from which is transmitted through a piece of opal glass and is diffusely reflected from the white internal surface *F*. *L* is adjusted to give *F* a brightness of about 8 candles per square metre, and the distances of the sources to be compared are then arranged so that the brightness of the field at *A* has approximately the same value. The test lamp and photometer are then fixed and measurements are made by moving the comparison lamp, the speed of rotation of *W* being reduced until flicker can be brought almost to disappear. Settings of the comparison lamp

are then made to the point of minimum flicker. The surfaces S and W are easily removable, so that they can be renewed by holding them over burning magnesium ribbon.

It will be noticed that the criterion of equality used in this instrument is not disappearance of flicker but minimum flicker, as it has been found that in practice this gives a rather more sensitive test of the balance point.

The whole basis of the flicker method is the experimental fact that colour flicker disappears at a much lower speed than brightness flicker, so that the judgment of brightness equivalence is not hampered by the presence of a colour difference as in the case of the ordinary steady comparison method. It is by no means self-evident, however, that the results obtained by the two methods should be the same, and as it is clearly most unscientific that the results of any measurements should depend on the method employed for that measurement, a great deal of experimental work has been carried out to determine the conditions under which the two methods give identical results. It has been found that this is the case when the following conditions are fulfilled for the flicker measurement :

- (a) a flicker field of about 2° diameter.
- (b) a field brightness of about 8 candles per square metre, i.e., a white surface having an illumination of 25 metre-candles.

Since a 2° field is very small, and is most trying to the eyes for continuous work, the flickering field should be surrounded with a steady extended field of the same or slightly lower brightness. These conditions, it will be seen, are fulfilled in the case of the instrument described above.

Another important matter which has to be considered in heterochromatic photometry is the degree to which different observers obtain the same results. Long experience has shown that when colour difference is absent, the extent of the difference between different observers, under normal conditions of field brightness, certainly does not exceed $\frac{1}{2}$ per cent. When there is a marked colour difference, however, the same cannot be said. Each individual differs slightly in the relative response which his eye makes to equal amounts of energy at different parts of the spectrum, and when two lights differ markedly in colour the relative values assigned to them will vary by, perhaps, 2 or 3 per cent., even among observers who would certainly be classed as having normal colour vision. In these circumstances it is clear that an accurate comparison is only possible if some convention be adopted as regards the eye of the observer making the measurement. The natural convention is to adopt as the basis of measurement the "average" eye of a large number of normal-sighted observers, and this is what is done in practice. Two colour solutions, one blue and one yellow, have been specified, so that the amount of light they transmit when placed in front of a tungsten lamp is exactly the same when measured by a large number of observers. The results obtained by any single observer are then corrected in accordance with his own particular blue/yellow ratio, i.e.,

the ratio of the transmission factors found for these specified colour solutions by the observer in question.

SPECTROPHOTOMETRY.

There is an important class of photometric measurement in which colour difference is definitely excluded. This is the comparison of the light given by two sources within a narrow range of wave-lengths. The instrument used for this type of measurement is called a spectrophotometer and consists of two essential parts. The first is a spectrometer or some similar means for enabling any given range of wave-lengths to be observed separately. The second is some device for bringing the lights from the two sources to the two parts of a comparison field and a means for altering the intensity of one part of this field.

A very convenient form of spectrophotometer is the Nutting-Hilger instrument shown in Figure 19.

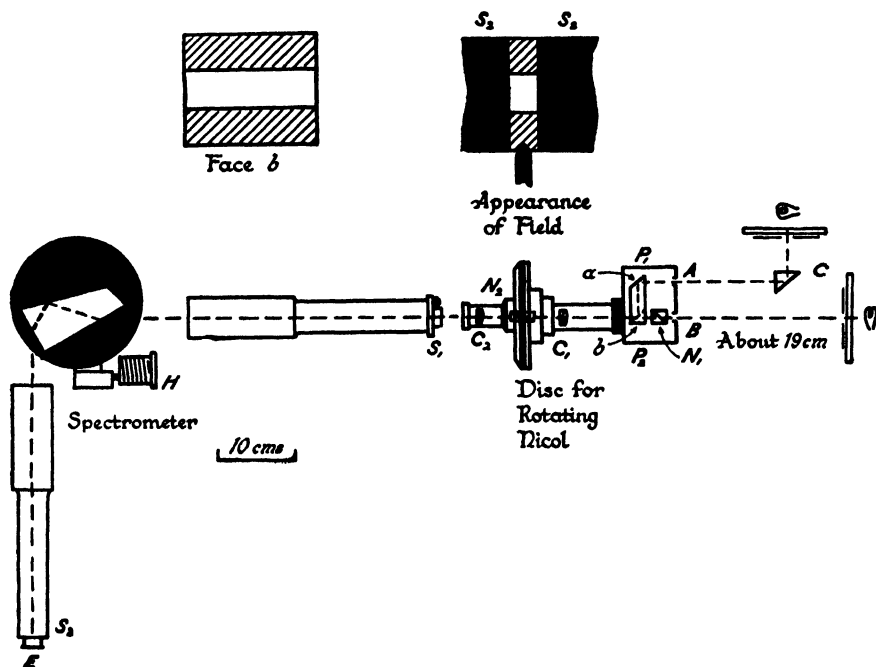


FIG. 19, The Nutting-Hilger Spectrophotometer.

The beams of light from the two sources to be compared are caused to fall respectively on the two apertures A and B of the photometer box. The beam entering the photometer at A is totally reflected at the face α of the prism P_1 , and again at the silvered upper and lower parts of the face β . This face, however, is in optical contact with the prism P_2 over a central horizontal

unsilvered strip about 2.5 mm. broad, as shown in detail in the figure. It follows that the light from A which reaches this band travels on without reflection, and is absorbed in the blackened wall of the photometer box. The light entering at B passes through a fixed nicol prism N_1 and is transmitted directly through the central parts of the prisms P_1 and P_2 , where the surface b is unsilvered, while the upper and lower parts of this beam are reflected to the wall of the box and there absorbed. Thus the beam leaving b consists of three parts, the upper and lower, unpolarised, from A, and the centre strip, plane polarised from B. This tripartite beam then passes through a second nicol prism N_2 , which is capable of rotation at will about its axis. The centre of the beam is therefore reduced in intensity by the factor $\cos^2\theta$, where θ is the angle between the optic axis of N_2 and the (fixed) axis of N_1 , while the light in the upper and lower parts of the beam, being originally unpolarised, is not altered in intensity. By means of the lenses C_1 and C_2 , the interface of the prisms P_1 and P_2 is focussed sharply on S_1 the slit of the spectrometer. The spectrometer acts in the ordinary way, so that the eye at E sees a continuous spectrum band formed of an infinite number of images of S_1 . The portion of this band which is in the centre of the field of view may be changed at will by moving the drum H, so as to turn the prism table. Any convenient portion of the band may be isolated by means of shutters in the eyepiece.

It will be seen that, since each part of the spectrum band seen at E is made up of images of S_1 , this band will consist of three horizontal strips as shown at the top of the figure. The light forming the top and bottom strips is that which has entered the instrument at A, while the light forming the central strip is that which has come from B and the intensity of which can be varied by rotating the Nicol prism N_2 . By this means it is clearly possible to find the ratio of the intensities of the two sources at any desired region of the spectrum. If this ratio be measured at a number of different spectral regions, a curve can be drawn to exhibit the intensity throughout the spectrum of any one source in terms of another.

As in ordinary photometry, the substitution method is generally employed. A comparison lamp is used to provide the beam entering the instrument at B, while the two sources to be compared are placed in turn so that they illuminate aperture A.

A very important application of spectrophotometry is to the determination of the spectral transmission curves of coloured glasses or other media. It will be clear that these curves can readily be obtained by using the same source to illuminate both the apertures A and B in the photometer, and placing the glass under measurement in front of A.

PHYSICAL PHOTOMETRY.

A subject which has long had an attraction for workers in photometry is that of finding some physical instrument which can be used in place of the eye,

so that it may be possible, not only to compare two sources placed side by side, but also to measure the luminous intensity of any source at any time, just as the temperature of a vessel of water can be measured with a thermometer. In fact, the lack of an instrument such as this was lamented by Lambert in 1760.

Many are the physical photometers that have been proposed. The rate of change in some chemical substance has been used. This form of physical photometer survives in the photographic method used in some classes of spectrophotometry and in stellar photometry. Another favourite instrument is the selenium cell, which depends upon the fact that the electrical resistance of the chemical element selenium is altered when light falls on its surface. This type of light detector is useful for many purposes in which accurate measurement is not needed, but for photometry it possesses the grave disadvantage of slowness both of response to stimulation and of recovery after removal of the light, as well as the defect common to all physical photometers, *viz.*, that its response to the same amount of energy in the form of light of different wavelengths is quite different from that of the eye. For instance, it favours the red at the expense of the green and yellow, and this effect, too, is more marked at high than at low intensities.

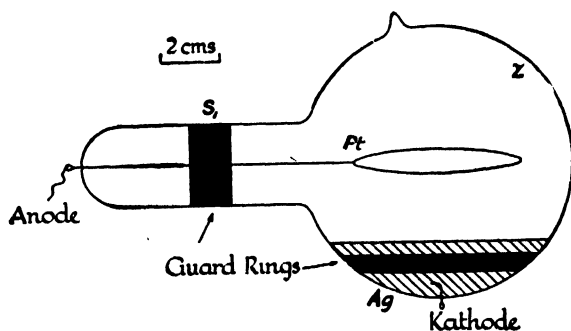


FIG. 20. The Photo-Electric Cell.

The most promising form of physical photometer is the photo-electric cell. This consists, as shown in Figure 20, of a glass globe, Z, into the centre of which projects a loop of gold or platinum wire Pt, which acts as the anode of the cell, while the cathode consists of a surface of alkali metal (Na, K, Rb or Cs or a K—Na alloy) which makes contact with a silver film Ag and a piece of platinum wire sealed into the glass. A guard ring S₁ connected to earth prevents leakage over the surface of the glass between the two electrodes. Sometimes the globe contains an inert gas, such as helium or argon at low pressure; otherwise the cell is pumped to as high a vacuum as possible.

The action of the cell depends on the effect, discovered by Hallwachs in 1888, that a negatively electrified metal surface, when suitably illuminated, loses its charge. This, as we now know, is due to the fact that illumination of the

surface causes it to give off electrons. If, therefore, light be allowed to fall on the metal surface in the globe, and a battery of, say, 60 volts be connected to the cathode and anode, the electrons liberated by the light will cause a minute current to pass round the circuit. This current is, under certain conditions, proportional to the illumination of the cathode surface, so that if a sensitive measuring instrument be included in the circuit, the readings will give a measure of the illumination.

Here, again, the response to light of different wave-lengths differs from that of the eye. It depends, too, on the metal used for the cathode. On the other hand, the action is instantaneous, and by taking suitable precautions it is possible to use such a cell for making accurate comparisons of two lamps giving light of exactly the same colour, such as, for instance, two tungsten filament vacuum lamps running at exactly the same efficiency.

The great attraction of this method of photometry is the promise it holds out of increased accuracy in photometric measurements. As long as the eye remains the only instrument of comparison available, it does not seem possible that any improvement in the accuracy now attainable (probably about 1 in a thousand) can ever be obtained. This limit is set by the fact that the contrast sensitivity of the eye is a physiological and not a physical quantity. With an instrument of the type of the photo-electric cell, however, no such fundamental difficulty exists. The only limitations are those set by the degree of perfection attainable in the manufacture of the cells and the accuracy with which it is possible to make the physical measurements involved.

STELLAR PHOTOMETRY.

It was mentioned at the beginning of these lectures that the earliest workers in photometry were astronomers, and stellar photometry is still a very important branch of the subject. It is, however, different in many respects from the type of measurement which has been considered up to the present. The stars are at such immense distances that the only photometric magnitude which can be measured with accuracy is the illumination which each produces at the earth's surface. This may be found by comparing a star visually with an artificial star by means of some arrangement such as that shown in Figure 21. The artificial star consists of a small aperture A in front of a source of light of known brightness. This source may conveniently be an electric lamp with an opal glass in front of it. The lens L forms an image of A, and this is reflected at the front surface of the glass plate M, and is seen by the observer at the telescope. By tilting M, the image of the real star and the reflected image of A may be brought close to each other for ease of comparison. The brightness of the artificial star image may be altered by means of the system of nicol prisms, just as in the case of the spectrophotometer. In this way the magnitude of one star may be compared with that of another. It may be of interest to mention that a first magnitude star, when at the zenith, produces an illumina-

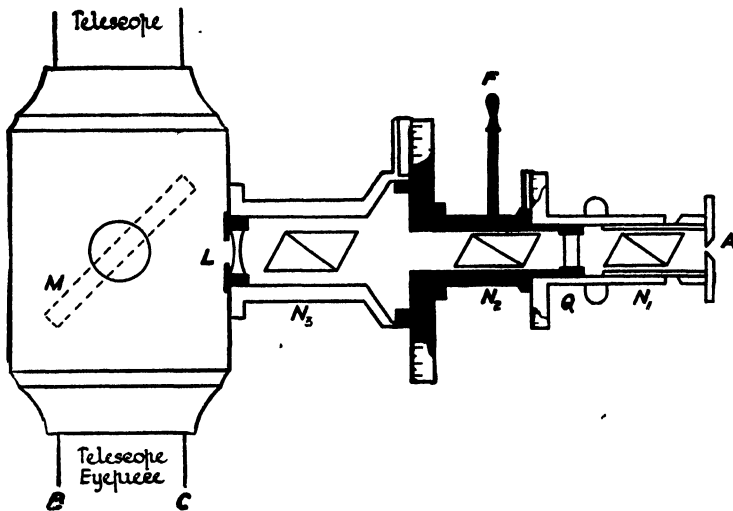


FIG. 21. A Visual Stellar Photometer.

tion of rather less than one ten-millionth of a foot-candle if the atmosphere be clear. A sixth magnitude star produces only one-hundredth of this illumination. Such a star is nearly at the limit of visibility by the naked eye, so that this fact gives an illustration of the extreme sensitivity of the human eye. It is, in fact, easy to show that a source of light of a luminous intensity of one international candle is visible on a clear dark night at a distance of about two miles.

Other methods of stellar photometry are now generally used. One of the most important is the photographic, in which the size or the density of the image of a star is compared with those of other stars of known magnitude which happen to be in proximity to it. An interpolation formula is used to eliminate the special characteristics of the plate.

Another method is the photo-electric, in which the light from the star falls on the sensitive surface of a cell such as that previously described. This method is especially useful for finding the light curves of periodically variable stars.

APPLICATIONS OF PHOTOMETRY.

This rapid survey of some of the more usual of the methods employed in modern photometry may, perhaps, be fittingly concluded with a brief mention of some of the applications of photometric measurement in modern engineering practice.

First of all, the photometry of lamps at the electric lamp factory may be mentioned. The output of the lamp factories in this country alone is about 40 millions a year, and these lamps are measured by sample to ensure that they comply with the British Standard Specification. The measurements

are made in sphere or cube photometers, since the lamps are rated in terms of luminous flux output, i.e., in lumens. The work is performed by girls, two of whom normally measure about 500 to 600 lamps per hour. One girl places the lamps in the sockets, puts them into the cube, notes the reading on the photometer and removes the lamp. The other girl makes the photometric measurements, moving the comparison lamp to the balance position for each fresh lamp inserted in the cube. It will be realised that the object of this work is not to make a definite measurement of the lumen output of each lamp, but simply to find out if the lumens given lie between the limits laid down in the specification.

Another very important application of photometric measurement is in that branch of engineering practice now known as illuminating engineering. In the first place the illumination necessary or desirable for various classes of work must be determined by experience. In the case of clerical work, for instance, the illumination has been measured in large numbers of offices, and it has been found that below about 3 foot-candles the light becomes noticeably insufficient, and, as a result of similar surveys, tables have been drawn up to indicate the minimum illumination desirable for various types of work. All these surveys rest on large numbers of measurements made with portable illumination photometers such as those described in the second lecture.

Once the illumination to be aimed at for any given purpose has been decided, the illuminating engineer has to design his installation to give this illumination at the points of work. In order to do this, he has to be furnished by the lamp-maker with figures for the luminous output from the different sizes of lamps available. More often than not, shades and reflectors are used to re-direct the light from the lamps and to distribute it over the working plane in such a way that it can be made use of to the best advantage. In such cases the illuminating engineer must know in what manner the light is distributed from these reflectors; in other words, he must have a polar diagram giving the luminous intensity of the whole unit, lamp and reflector, in all directions. This polar curve is obtained by the maker of the reflectors in his photometric laboratory, and in most up-to-date catalogues of lighting fittings there will be found the polar diagrams of light distribution appropriate to each fitting listed.

The life-testing of electric lamps is a subject which has not been mentioned before, as it is not, strictly speaking, a branch of photometry. Every lamp works, however, and every large consumer of electric lamps, makes periodical tests of the behaviour of electric lamps during the period of operation. Figure 22 shows a rack at the National Physical Laboratory on which lamps are tested for life in accordance with the British Standard Specification. Lamps chosen as representative of a consignment are measured initially for luminous output. They are then set up on this rack and are run continuously at such a voltage that their efficiency is equal to that stated in the specification. Photometric

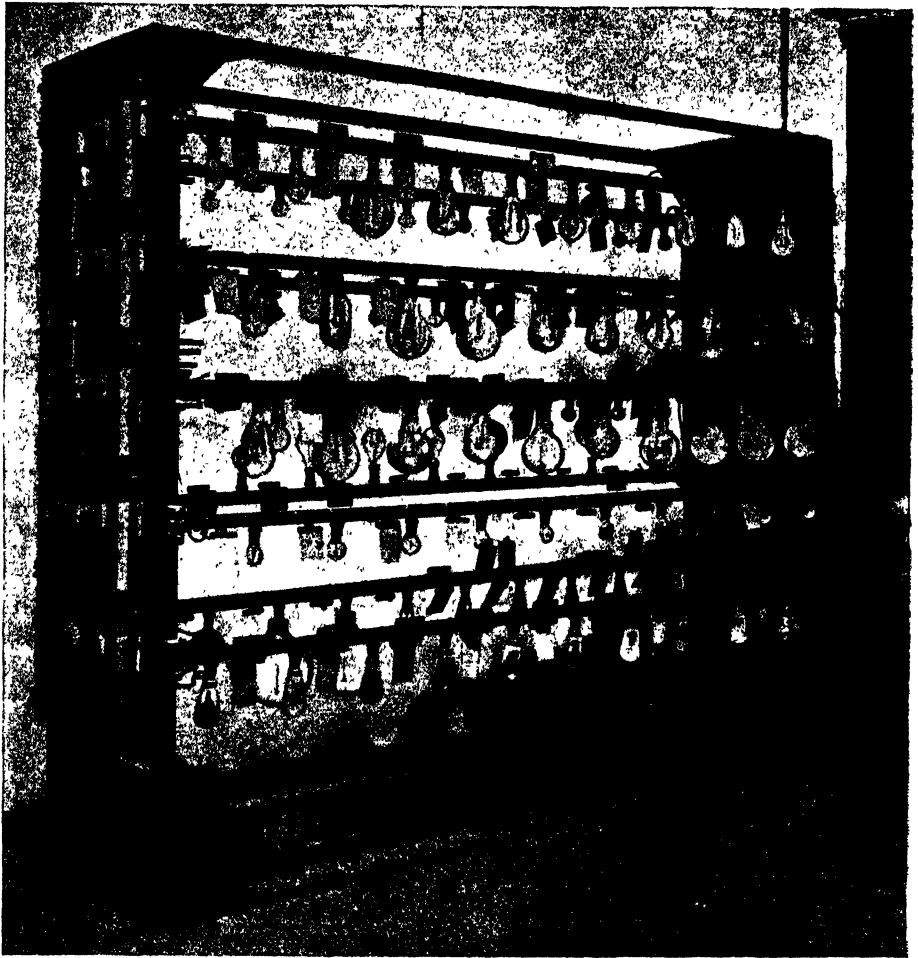


FIG. 22. A frame for life-testing electric lamps.

measurements are made after 100, 200, 300, 500, 750 and 1000 hours of burning, and the total lumen-hours are computed to determine whether the lamps comply with the specification. It should be noted that the voltage of the supply is carefully regulated since a one per cent. rise in the voltage, if permanent, would cause a decrease of about 7 per cent. in the life of the lamps.

There are many practical applications of photometry which require special treatment. Most important of these, perhaps, is the testing of projection apparatus, such as lighthouse projectors and signal lamps of various kinds. It will readily be understood that ordinary photometric methods cannot be applied without modification in such cases. The inverse square law, for instance, is based on the assumption that the dimensions of the light source are small

compared with its distance from the photometer, or, in other words, that the rays of light may be regarded as radiating from a point.

In a lens system such as that of a lighthouse, for instance, the rays of light are changed in direction so that they can no longer be regarded as radiating from a point except when the photometer is at very great distances. It is therefore necessary, either to make measurements at distances of, perhaps, half a mile or more from the lens, or else to use a diaphragm with an aperture in it, and to expose only a small portion of the lens at a time. In this way the candle-power of the beam coming from each part of the lens can be measured with a photometer at distances obtainable in a laboratory, and the candle-power of the whole beam is then found by adding the candle-powers of the various portions. The same method may be applied in the case of large searchlight projectors.

Lighthouse lenses and searchlight mirrors are designed, usually, to give the nearest possible approximation to a parallel beam of light. For certain purposes, however, a beam with a given candle-power distribution is required. In the case of ships' navigation lights, for example, a beam of too narrow a vertical divergence is undesirable, since a slight heel of the ship causes the light to become invisible at moderate distances. It has been laid down, therefore, that the beam from such a light must have approximately the same candle-power for five degrees above and below the horizontal; in fact, the curve marked A in Figure 23 shows the minimum candle-power at different angles. The curve

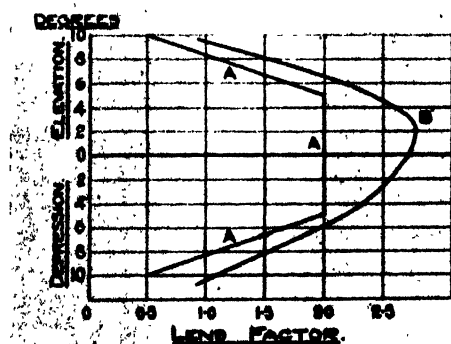


FIG. 23. Diagram shewing distribution of light. The lines A shew the required minimum distribution of light from a side or mast-head lantern. The curve B shews the actual distribution of light given by a side lens made to the design described in the paper.

found by photometric measurement of an actual light is shown by the line marked B. This curve was obtained by placing the light on a tilting table and measuring the beam candle-power on a photometer bench in the usual way, except that it was found necessary, in order to apply the inverse square law, to have the photometer head always 5 metres or more from the light.

A somewhat similar problem is presented by an automobile headlight, which includes some reflecting or similar device designed to reduce the candle-power in directions above the horizontal and so to mitigate the glare to other drivers. In this case measurements are usually made at distances of about 40 feet from the headlight, a tilting table being used as before.

An altogether different problem is that of measuring the brightness of the compound used for the luminous markings on watches and other instruments. This compound consists of a specially prepared zinc sulphide mixed with a very small proportion (about 1 part in ten-thousand by weight) of a radium salt, and its brightness when new is of the order of that of a white surface illuminated by the light of the full moon, *viz.*, about 0.02 foot-candle. This compound was very much used during the War, and many samples were measured at the National Physical Laboratory, on the apparatus shown in Figure 24. S is a

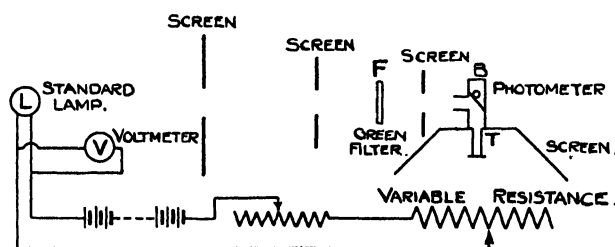


FIG. 24. Diagram of apparatus for measuring the brightness of radium luminous compounds.

sheet of matt white celluloid, having at its centre an oblong aperture, so proportioned that when looked at through the telescope T it has the appearance of a small square. This aperture is cut with a sharp bevel to ensure as little separation as possible at the edges. The luminescent compound is contained in a glass tube G, and wedge-shaped guides are arranged inside the box to assist in placing it centrally behind the aperture in S, no matter what the diameter of the tube. The celluloid sheet S is illuminated by a standardised lamp, the light from which, after passing through a green glass or gelatine filter, enters the box at O. The illumination at S is calculated from the candle-power and distance of the lamp, a constant factor being applied to convert from the illumination of S to its brightness as viewed from T, and to allow for the transmission factor of the green filter.

It was known that the brightness of the compound diminished with lapse of time, and, further, that it could be much reduced by unskilful application to the instrument dials in the form of paint. A method had therefore to be devised for measuring approximately the brightness of the markings on the painted dial. The instrument used for this purpose is shown in Figure 25. L is an electric lamp, the light from which, variable at R, passes through a green filter F and illuminates two screens S, S, each consisting of two sheets of thin white paper with a space between them. This arrangement ensures

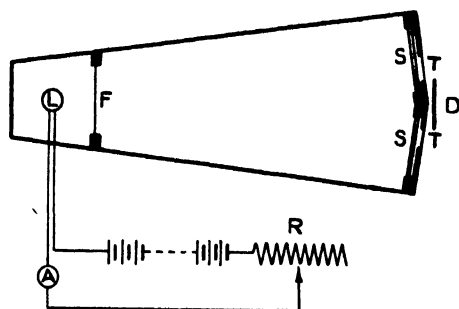


FIG. 25. Diagram of apparatus for measuring the brightness of the markings of luminous dials.

perfect diffusion of the light and even brightness over the whole surface of the second sheet. In front of the screens are placed two stencils, T, T, each consisting of a sheet of thin brass with figures or markings cut on an engraving machine so as to be identical with the luminous markings of the dials under examination. Two comparison dials are used, one on each side of the test dial, so as to overcome errors due to inequalities in sensitivity to green light on different parts of the retina. The instrument is calibrated by measuring, for different values of the current passing through the lamp, the brightness of the surfaces immediately behind T, T, using for this purpose a surface-brightness photometer. Over 50,000 dials, the majority for aircraft instruments, were measured on this apparatus during the war.

It will be understood that it has only been possible in the time available to give a very sketchy outline of the principles and processes of the measurement of light. If sufficient has been said to show that this branch of metrics presents its own peculiar problems and has its own fascination for those who have occasion to interest themselves in it, the object of these lectures will have been served.

In conclusion, I should like to thank my colleagues in the Photometry Division of the N.P.L. who have helped me with their accumulated experience, and especially Dr. Harrison, who arranged the demonstration of the photo-electric cell, Mr. Brookes, who prepared the slides, and Messrs. MacManus and Lambert, who have helped me with the arrangement of the experiments. I also desire to express my acknowledgments to Messrs. Constable & Company for the loan of the blocks used for reproducing certain of the diagrams from my book on *Photometry*, published by them, and to the Institution of Electrical Engineers for the loan of blocks for diagrams Nos. 5 and 7 in the first lecture, which are reproduced from my paper entitled "Illuminating Engineering," recently read before the Institution.

GENERAL NOTES.

INTERNATIONAL DESIGN COMPETITION AT COMO.—A number of valuable prizes and four gold medals have been recently awarded in the Salterio competition at Como. Although confined to designs for ties, the competition was an important one and attracted a large number of competitors throughout the world. The jury included representatives of several European countries, the representative of Great Britain and the Dominions being Mr. Selwyn Brinton, a Fellow of the Society. The group of designs sent in from Great Britain and the Dominions was not large, but included some good designs. Miss Edith Ashby, of the Fulham Art Schools, and Mr. Charles Humphry, were each awarded prizes of 1,000 lire. Good designs were also sent in from Canada and the Transvaal, but were unfortunately in both cases disqualified for an award owing to non-compliance with the regulations.

EIGHTEENTH ANNUAL EXHIBITION OF THE PHYSICAL SOCIETY AND THE OPTICAL SOCIETY.—The Eighteenth Annual Exhibition of Electrical, Optical and other Physical Apparatus will be held by the above Societies on January 10th, 11th and 12th, 1928, at the Imperial College of Science and Technology, South Kensington. As in previous years, the Exhibition will include the Trade Section, comprising the exhibits of manufacturing firms; and the Research and Experimental Section, initiated in 1926, will again be included. In the latter Section the Groups are:—(a) Exhibits illustrating the results of recent physical research and improvements in laboratory practice; (b) Effective lecture experiments; (c) Repetitions of historical experiments. The Exhibition Committee invites offers from Research Laboratories and Institutions and from individual research workers, of suitable exhibits for the Research and Experimental Section. Accommodation for the latter will be provided in rooms separate from those devoted to the trade exhibits; and a part of the Catalogue will be allotted to their description. No charge will be made for space or catalogue entries in this Section, and the facilities of the Imperial College will be at the disposal of the exhibitors. Offers of Exhibits in the Research and Experimental Section should be communicated immediately, and in any case not later than November 16th, to the Secretary, Physical and Optical Societies, 1, Lowther Gardens, Exhibition Road, London, S.W. 7. Brief particulars of space and other facilities required should be given.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, NOVEMBER 7. Architects, Royal Institute of British, 9, Conduit Street, W. 8 p.m. Inaugural Meeting, Presidential Address.
British Empire Producers' Organisation, at the Royal Society of Arts, Adelphi, W.C. 4.30 p.m. Mr. Harold T. Pooley, "The Producer in the Caribbean Colonies."
Chemical Industry, Society of, at Burlington House, W. 8 p.m. Mr. E. R. Bolton, "Recent Advances in the Hydrogenation of Oils—General Introduction"; Mr. K. A. Williams, (a) "Selective Hydrogenation"; (b) "Melting Point of Hydrogenated Oils"; Mr. R. G. Pelly, "Hydrogenation of Fatty Acids and Neutral Oils"; Mr. E. J. Lush, "The Activity of a Nickel Catalyst."
Electrical Engineers, Institution of, Savoy Place, W.C. 7 p.m. Mr. C. H. Holbeach, "Recent Developments in Electro-Medical Appliances."

At the University, Liverpool. 7 p.m. Mr. W. McClelland, "The Applications of Electricity in Warships."
Geographical Society, at the Aeolian Hall, New Bond Street. 8.30 p.m. Dr. Laue Koch, "A Recent Journey in East Greenland."
Petroleum Technologists, Institution of, at the Royal Society of Arts, Adelphi, W.C. 5 p.m.
Philologie Sciences et Beaux-Arts, Société Internationale de, 8, Taviton Street, W.C. 3.30 p.m. Mr. Patrick Braybrooke, "Literature in 1927."
Royal Institution, 21, Albemarle Street, W. 5 p.m. General Meeting.
Transport, Institute of, at the Queen's Hotel, Birmingham. 6 p.m. Mr. H. G. Waggett, "The Problem of the Small Consignment."
University of London, at the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Prince D. Svyatopolk Mirsky, "The Russian Novel, 1845-1880." (Lecture V.)
At University College, Gower Street, W.C. 5.15 p.m. Dr. E. A. Hauser, "The Colloid Chemistry of the Rubber Industry." (Lecture I.)

- TUESDAY, NOVEMBER 8.** Anthropological Institute, at Burlington House, W. 8.30 p.m. Dr. Alĕs Hrdlička, "The Neanderthal Phase of Man." (Huxley Memorial Lecture.)
- Arts, Royal Academy of, Burlington House, W. 4.30 p.m. Prof. Dr. Arthur Thomson, "A Rapid Survey of the Main Features of the Anatomy of the Upper Limb."
- Electrical Engineers, Institution of, at the Royal Technical College, Glasgow. 7.30 p.m. Mr. W. McClelland, "The Applications of Electricity in Warships."
- Oil and Colour Chemists' Association, at 30, Russell Square, W.C. 7.30 p.m. Prof. T. M. Lowry, F.R.S., "The Scattering of Light by Suspended Particles—the Properties of Powders."
- Photographic Society, 37, Russell Square, W.C. 7 p.m. Meeting of the Scientific and Technical Group.
- Physiology, London College of, 8, Tavistock Street, W.C. 8.15 p.m. Dr. J. Barker Smith, "Nutrition, Reproduction and their Sublimation."
- Quekett Microscopical Club, 11, Chandos Street, W. 7.30 p.m. Mr. Eric Ashby, "The Laws of Plant Growth."
- Royal Institution, 21, Albemarle Street, W. 5.15 p.m. Sir J. H. Parsons, "Light and Sight." (Lecture II.)
- Sanitary Institution, 90, Buckingham Palace Road, S.W. 5.30 p.m. Major H. Barnes, "The Royal Commissions on Health and Housing: A Retrospect and Forecast."
- Transport, Institute of, at the Institution of Electrical Engineers, Savoy Place, W.C. 6 p.m. Mr. A. Earle Edwards, "A Comparison between operation of the German State Railways and the Etat and Nord Railways of France."
- Wireless Technology, Institute of, at the Engineers' Club, Coventry Street, W. 7 p.m. Messrs. W. B. Medlam and U. A. Oschwald, "A Note on the Performance of Valve Detectors."
- University of London, at the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Sir Bernard Pares, "Russian History to 1861." (Lecture V.)
- at King's College, Strand, W.C. 5.30 p.m. Prof. R. M. Dawkins, "The Greeks in Asia Minor."
- WEDNESDAY, NOVEMBER 9.** Civil Engineers, Institution of, Great George Street, S.W. 6 p.m.
- Egypt Exploration Society, at Burlington House, W. 8.30 p.m. Mr. S. R. K. Glanville, "Amenophis III."
- Electrical Engineers, Institution of, at the University, Birmingham. 7 p.m. Mr. F. Forrest, "Economic Aspects of Pulverized Fuel": Prof. A. W. Nash, "Present and Future Possibilities of Extracting Oil from Coal": Prof. K. N. Moss, "Coal Analysis in relation to Heat Value for Steam Raising."
- Mechanical Engineers, Institution of, at Mappin Hall, Sheffield. 7.30 p.m. Sir William H. Bragg, "Application of X-Rays to the study of the Crystalline Structure of Materials." (Thomas Hawksley Lecture.)
- Metals, Institute of, at Thomas' Café, High Street, Swansea. 7 p.m. Dr. Peter Macnair, "Pyrometers in Works Practice."
- North-East Coast Institution of Engineers and Shipbuilders, at Bolbec Hall, Newcastle-upon-Tyne. 7.15 p.m. Mr. F. H. Todd, Chairman's Address.
- At the Cleveland Scientific and Technical Institution, Middlesbrough. 7.15 p.m. Mr. J. Pilgrim, "Valves and Valve Gear."
- Public Health, Royal Institute of, 37, Russell Square, W.C. 4 p.m. Lt.-Col. F. E. Fremantle, "The Present Situation in regard to Housing."
- University of London, at the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Dr. Otakar Vocař, "English and American Influences in Czech Literature." (Lecture I.)
- At King's College, Strand, W.C. 5.30 p.m. Dr. Cyril Norwood, "Secondary Education: The Boys' Boarding School."
- At King's College, Strand, W.C. 5.30 p.m. The Very Rev. the Dean of Salisbury, "The Mystery Religions." (Lecture I.)
- At the London School of Economics, Houghton Street, Aldwych, W.C. 6 p.m. F. R. M. de Paula, "Accounts as an Aid to Management."
- At University College, Gower Street, W.C. 3 p.m. Dr. Pellizzi, "Dante in alcuni giudizi contemporanei." (in Italian). (Lecture II.)
- 5.30 p.m. Mr. I. C. Gröndahl, "Regions and Place-Names in Norway." (Lecture I.)
- At University College, Gower Street, W.C. 5.15 p.m. Dr. E. A. Hauser, "The Colloid Chemistry of the Rubber Industry." (Lecture II.)
- THURSDAY, NOVEMBER 10.** Abattoir Society, The Model, at 90, Buckingham Palace Road, S.W. 5.30 p.m. Lt.-Col. Gerald Leighton, M.D., "The Modern Abattoir and its Place in Public Health Administration." (Benjamin Ward Richardson Memorial Lecture.)
- Chadwick Public Lecture, at the Royal Society of Arts, Adelphi, W.C. 8.15 p.m. Major Harry Barnes, "The History of Housing—Housing before 1885."
- Decorators, Incorporated Institute of British Painters' Hall, Little Trinity Lane, E.C. 7.30 p.m. Mr. Shadrach Hicks, "The Appropriate Decoration to accompany Period Furniture."
- Electrical Engineers, Institution of, at University College, Dundee. 7.30 p.m. Mr. A. S. McWhirter, "Electrical Repairs to Motors and Dynamos."
- Historical Society, 22, Russell Square, W.C. 5 p.m. Mrs. C. H. Ashdown, "English Historical Costume."
- L.C.C. The Geoffrey Museum, Kingsland Road, Shoreditch, E. 7.30 p.m. Mr. Walter G. Bell, "The Great Fire of London."
- Mechanical Engineers, Institution of, at the Hotel Metropole, Leeds. 7.30 p.m. Sir William H. Bragg, "Application of X-Rays to the study of the Crystalline Structure of Materials." (Thomas Hawksley Lecture.)
- At Cardiff, Mr. C. J. T. Billingham, Chairman's Address.
- Metals, Institute of, at the Royal School of Mines, South Kensington, S.W. 7.30 p.m. Mr. C. C. Paterson, "Some Metallurgical Problems of the Electrical Industry."
- Photographic Society, 35, Russell Square, W.C. 7 p.m. Mr. James Rowatt, "The Lignose Colour Process."
- Royal Institution, 21, Albemarle Street, W. 5.15 p.m. Mr. H. Clifford Smith, "Furniture of the Mediaeval House." (Lecture II.)
- University of London, at Bedford College for Women, Regents Park, N.W.1. 4.15 p.m. Prof. Eccles, "Voltaire: les meilleurs moments et les plus belles pages." (Lecture VI.)
- At the Imperial College of Science, South Kensington, S.W. 5.45 p.m. Mr. R. H. Fowler, "Statistical Mechanics, Old and New." (Lecture I.)
- At King's College, Strand, W.C. 5.15 p.m. Mr. H. Broxap, "Jacobites and Non-Jurors."
- 5.30 p.m. Rev. Canon Evan Roberts, "Hymnody of the Eighteenth Century."
- 5.30 p.m. Mr. Ifor L. Evans, "Peasant Proprietorship in South-Eastern Europe." (Lecture IV.)
- At University College, Gower Street, W.C. 5.30 p.m. Miss E. Jeffries Davis, "London Place-Names." (Lecture I.)
- 5.15 p.m. Prof. de Montmorency, "Customary Law in the British Empire." (Lecture II.)
- At the Victoria and Albert Museum, South Kensington, S.W. 5.30 p.m. Mr. C. M. Weekley, "Alphabets."
- FRIDAY, NOVEMBER 11.** Mechanical Engineers, Institution of, Storey's Gate, S.W. 7 p.m. Mr. Fred Clements, "What is wrong with Industrial England?"
- Philologie, Sciences et Beaux-Arts, Société Internationale de, 8, Tavistock Street, W.C. 8.15 p.m. Dr. Norman Morrison, "Druidism."
- Physical Society, at the Imperial College of Science, Imperial Institute Road, S.W. 5 p.m.
- Transport, Institute of, at the Town Hall, Newcastle-upon-Tyne. 5 p.m.
- University of London, at University College, Gower Street, W.C. 5.15 p.m. Dr. E. A. Hauser, "The Colloid Chemistry of the Rubber Industry." (Lecture III.)
- SATURDAY, NOVEMBER 12.** L.C.C. The Horniman Museum, Forest Hill, S.E. 3.30 p.m. Mrs. Robert Aitken, "Dances of the Pueblo Indians."
- Royal Institution, 21, Albemarle Street, W. 3 p.m. Mr. E. Cammaerts, "Main Features of the Modern English Literature." (Lecture II.)
- Mathematical Association, at Bedford College, Regents Park, N.W. 3 p.m. Mr. C. V. Durell, "An introduction to Relativity for Post-matriculation Non-specialists."

JOURNAL OF THE ROYAL SOCIETY OF ARTS

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VOL. LXXV.

FRIDAY, NOVEMBER 11th, 1927.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2.)

NOTICE.

NEXT WEEK.

MONDAY, NOVEMBER 14th, at 8 p.m. (Cantor Lecture.) PROFESSOR H. C. H. CARPENTER, M.A., A.R.S.M., F.R.S., "Alloy Steels, their Manufacture, Properties and Uses." (Lecture I.)

WEDNESDAY, NOVEMBER 16th, at 8 p.m. (Ordinary Meeting.) PROFESSOR LEONARD HILL, M.B., F.R.S., Hon. A.R.I.B.A., "Overcrowding in Public Conveyances." THE RIGHT HON. LORD DAWSON OF PENN, G.C.V.O., K.C.B., K.C.M.G., M.D., D.C.L., will preside.

FUND FOR PURCHASING THE SOCIETY'S HOUSE.

The following contributions to the Fund for Purchasing the Society's House have been received since the last list was published :—

			£	s.	d.
Amount previously acknowledged	...	...	43,379	11	5
Herbert Cordingley, Esq.	...	...	6	6	0
A. C. Eborall, Esq., M.Inst.C.E.	...	...	5	5	0
Miss Le Neve Foster	...	...	5	5	0
Miss Emma S. Boyd	...	...	5	0	0
Robert W. Maxwell, Esq.	...	...	7	0	
			£43,401	14	5

Fellows of the Society are reminded that the amount aimed at by the Council is £50,000, which, in addition to purchasing the freehold, will cover the cost of renovating and decorating the house.

FIRST ORDINARY MEETING.

WEDNESDAY, NOVEMBER 2nd, 1927. SIR PHILIP MAGNUS, Bt., Chairman of the Council, delivered his Inaugural Address on "The Royal Society of Arts: its Services to Trade and Training."

The Society's Silver Medals awarded for Papers read during the Session 1926-27 were presented by the Chairman.

The Chairman's Address will be published in the *Journal* dated November 18th.

ROYAL SOCIETY OF ARTS.

REPORT ON THE SOCIETY'S EXAMINATIONS, 1927.

Considerable developments in connexion with the Society's Examination system have taken place during the last year. In addition to the three series of Evening Commercial examinations which are now held regularly at Easter, Whitsuntide and in July, two further sets of examinations were instituted this summer. The first of these was an examination for certificates of two grades, known as the School and Junior School Certificates, and the second, undertaken at the request of the London County Council, were Group Course Examinations for students at L.C.C. Junior Commercial and Junior Technical Institutions. A brief report on these new examinations will be found on pages 1220 and 1223. Meantime it may be mentioned that as a result of them the total number of papers worked this year is again a record, the figure being 88,088, as compared with 83,246 in 1926. Of these 78,142 were worked at the Evening Examinations. This figure shows a decrease of 5,104, as compared with the total for 1926. The reduced number is due to the discontinuance of the examinations in Commercial Correspondence (for which there were 3,909 entries last year) and to the fact that a large number of candidates from the L.C.C. Commercial Institutes, who in previous years took the ordinary evening examinations, in 1927 took the new Group Course Examinations specially provided for them.

Surprise is very often expressed at the very large numbers who take the Society's Examinations. The fact is that they meet the wants of an enormous class of students for whom no other provision is made. It is the fashion in certain quarters to belittle the value of examinations and even to condemn them utterly as educational dangers. This is, perhaps, hardly the place to fight over again the old battle of external and internal examinations; but the Council is strongly of opinion that the average student works better when he has a definite goal in view, and he has long ago found out that his chances of securing employment are greatly improved if he can produce unbiassed evidence of his capabilities, such as a certificate of the Royal Society of Arts

affords. The value of this certificate is recognised more and more clearly every year by employers, and is probably as well known in Aberdeen as in London.

EVENING COMMERCIAL EXAMINATIONS.

The Evening Commercial Examinations were held at three periods, April, May-June and July. In April the number of entries was 28,799, in May, 39,662, and in July, 13,479. The papers worked were divided among the three Examinations as follows :—

	April.	May.	July.	Total.
Advanced Stage	2,906	6,905		9,811
Intermediate Stage	9,080	16,425	4,564	30,069
Elementary Stage	16,813	16,332	8,915	42,060

In addition to the 78,142 papers worked in the written examinations, 629 candidates presented themselves for the *viva voce* Examinations in Modern Languages.

The subjects of Examination this year were :—

Arithmetic.	Foreign Exchange.
English.	Commerce.
Book-keeping.	Railway Law and Practice.
Shorthand.	Railway Economics.
Typewriting.	Shipping Law and Practice.
Economic Geography.	Stock Exchange Law and Practice.
Economic and Social History.	Advertising and Salesmanship.
Economic Theory.	French.
Précis-writing.	German.
Commercial Law.	Italian.
Company Law.	Spanish.
Accounting.	Russian.
Banking.	Portuguese.
Costing.	

Arithmetic.—The total number of papers worked in all three stages this year was 10,533, as compared with 10,773 papers last year. Of the 322 papers worked in Stage III, 72 papers gained first-class certificates, 133 papers gained second-class certificates, and 117 failed. The high percentage of failures on which the Examiner commented last year (183 out of 309) has been considerably reduced this year, while the proportion of first-class certificates (72 out of 322, as compared with 30 out of 309 in 1926) has correspondingly increased.

In Stage II, out of 2,649 papers sent in, 603 papers obtained first-class certificates, and 994 papers obtained second-class certificates, the number of

failures being 1,052. The Examiner reports that whilst there were many excellent papers, a large number of candidates were ill-prepared and often very inaccurate. Among the commonest causes of failure are ignorance of Bankers' Discount and confusion in taking percentages.

In Stage I there were 7,562 candidates, of whom 964 passed with credit, 4,129 passed, and 2,469 failed. The results in mental arithmetic show improvement, although in some centres enough attention is not given to the decimalisation of money. In the written papers also, the style appears to be improving from year to year; but many of the weaker candidates do not seem to realise the fact that it is as important to show their methods of working as to get a correct answer.

English.—The number of candidates in this subject was 6,845. In Stage III there were 351, of whom 23 obtained first-class certificates, 197 obtained second-class certificates, and 131 failed. A question of a somewhat unfamiliar character produced some good results. A table of vital statistics was given which the candidates were asked to study and then to write a short account of them, such as might interest the general reader. Another unusual test was set in the question which asked candidates to study a given map of Poland and then to write an account of the economic resources of the country. On the whole the answers were well done, and the exercise proved to be a good test of intelligence and clear, concise expression. The Examiner finds it necessary to comment once more on the tendency to pointless verbiage manifested in the essays by many candidates, who have acquired some fluency in writing without the mental discipline which should control it. Candidates at this Stage ought to know that Wordsworth was not an American poet, nor should they attribute to him the authorship of *L'Allegro* and *Il Penseroso*.

In Stage II there were 2,022 candidates, of whom 121 obtained first-class certificates, 1,327 obtained second-class certificates, and 574 failed. A good many marks were lost through careless reading of the instructions. Generally speaking, the essays were good, and there was less reason than usual to find fault with the handwriting, though the spelling was occasionally deplorable. The answers to the *précis* question were often weak, the commonest faults being a tendency to cling too slavishly to the language of the original passage, and to write at too great length. The prescribed books had evidently been carefully studied in most cases.

In Stage I, of 4,472 candidates, 110 passed with credit, 2,540 passed, and 1,822 failed. Here, again, the prescribed books had generally been well prepared. On the whole, the average standard of attainment was satisfactory, but, as usual in English at this stage, there were a considerable number of candidates who were below any reasonable examination standard.

* i.e., obtained not less than 80 per cent. of the total number of marks.

Book-keeping.—This continues to be easily the most popular subject in the Society's Examinations. The total number of papers worked was 23,006, as compared with 23,407 in 1926. In Stage III there were 3,860 candidates, of whom 433 obtained first-class certificates, 1,680 obtained second-class certificates, and 1,747 failed. Many candidates appeared to be puzzled as to how to enter a "loss," while "costing," a subject of growing importance, seemed to have been neglected by many more.

In Stage II, of 8,727 candidates 1,945 obtained first-class certificates, 4,730 obtained second-class certificates, and 2,052 failed. The percentage of failures, 23.5, is satisfactorily small. The exercises, as a rule, were well worked, but any items at all out of the ordinary caused many candidates to get into difficulties.

In Stage I, there were 10,419 candidates, of whom 716 passed with credit, 4,970 passed, and 4,733 failed. The Examiner comments on the fact that a good many students are still being trained in archaic methods which have long since been abandoned in modern practice.

Shorthand.—The total number of candidates in this subject was 16,128. In Stage III there were 1,502, of whom 135 passed the 140 words-per-minute test, 547 passed the 120 words-per-minute test, and 820 failed. The transcripts of the medal papers were quite as good as, if not better than, any which have been sent in for some years past. Most of the mistakes to which the Examiner draws attention would seem to be due to limitations of general education, a number of words in fairly common use seeming to be unfamiliar to the students.

In Stage II there were 7,511 candidates; 799 passed the 100 words-per-minute test, 3,208 passed the 80 words-per-minute test, and 3,504 failed. It is interesting to note that 10 papers were worked by blind candidates, of whom 6 passed at 100 words-per-minute; one failed at that speed, and 3 passed at 80 words-per-minute. As usual there were a considerable number of misspellings and mis-renderings, such as "tobacco" and "tabbioco" for "tapioca," "easy one" for "acid scent," and various versions of "syndicalism".

In Stage I there were 7,115 candidates, of whom 2,869 passed the 60 words-per-minute test, 2,209 passed the 50 words-per-minute-test, and 2,037 failed. The Examiner points out the great importance of students providing themselves with paper of suitable size and quality for taking shorthand notes. It is no exaggeration to say, he reports, that nearly one-half of the notes sent in are written on paper quite unsuitable for the purpose. This carelessness no doubt adds considerably to the number of failures, and it is hoped that in future candidates will not add to their difficulties by this quite unnecessary handicap.

Typewriting.—The number of candidates in this subject was 8,842, an increase of 585 over the total for 1926. In Stage III there were 878, of whom

245 obtained first-class certificates, 475 obtained second-class certificates, and 158 failed. The work, on the whole, was satisfactory, but the examiner thinks that it would be improved if accuracy and not speed were recognized as the chief consideration.

In Stage II, of 3,354 candidates, 1,009 obtained first-class certificates, 1,596 obtained second-class certificates, and 349 failed. The high proportion of first-class passes and the low proportion of failures are very satisfactory. As a rule the manipulation of the machine was very good, but unfortunately the work of many candidates was marred by extraordinarily bad spelling.

In Stage I there were 4,610 candidates, of whom 882 passed with credit, 2,743 passed, and 985 failed. Here, again, a great many candidates lost marks by atrocious spelling. A typist who mis-spells simple words of one syllable is not likely to be of much use to anyone.

Economic Geography.—The number of candidates who entered for this subject was 1,105. In Stage III there were 61, of whom 9 obtained first-class certificates, 33 obtained second-class certificates, and 19 failed. The Examiner finds that the work is marked by distinctly improved regional and descriptive answers, and a general absence of irrelevant matter, especially in descriptions of climate, which used to be characterised by vagueness and irrelevance. In cases where analysis was required, however, the answers were often poor.

In Stage II there were 296 candidates, of whom 41 obtained first-class certificates, 176 obtained second-class certificates, and 79 failed. The papers worked in April, though few in number, were admirable in quality: indeed, they are described by the Examiner as "the best set of papers ever sent in for Stage II" and as showing "more thoroughly scientific progress than he remembers in any stage in two consecutive years." The general standard of work, especially with regard to sketch-mapping, is slowly but quite steadily rising. There seems to be no doubt that the reports of the Examiner, which are always very full and carefully point out the leading faults of the examinees, are carefully studied both by teachers and candidates.

In Stage I there were 748 candidates, of whom 76 passed with credit, 443 passed, and 229 failed. The reduction of the length of the examination in this stage from three to two hours, and the consequent shortening of the paper from seven to five questions, seems to have helped the better candidates and handicapped the feebler. The Examiner is unfortunately compelled to comment on the spelling of many candidates as "both atrocious and unpleasantly suggestive—of neglect of the atlas. Nothing else can account for the large proportion of 'phonetic' spelling, e.g., Norige—Norwich. . . . The marvellous thing is that the teachers concerned do not realise how obviously gross neglect of the atlas means wholesale failure in the examination."

Economic and Social History.—There were 186 entries in this subject. In Stage III, of 21 candidates 7 obtained first-class certificates, 13 obtained

second-class certificates, and 1 failed. The proportion of clear, straightforward work showing full and accurate knowledge, was considerable, and there was a satisfactory amount of creditable performance in which facts were firmly known and properly related to each other. In Stage II there were 54 candidates, of whom 7 obtained first-class certificates, 32 obtained second-class certificates, and 15 failed. The work here was of mediocre quality, and the knowledge shown was often scrappy and uncertain. In Stage I, of 111 candidates 16 passed with credit, 80 passed and 15 failed. The general result was satisfactory, and the Examiner thinks that the quality of the work done in this stage has shown a gratifying advance since the examination was instituted a few years ago, and that this year the advance has been marked.

Economic Theory.—The number of candidates was 515. In Stage III there were 227, of whom 37 obtained first-class certificates, 128 obtained second-class certificates, and 62 failed. A majority of the papers reached a creditable level of adequate and accurate knowledge. In Stage II, of 228 candidates 29 obtained first-class certificates, 200 obtained second-class certificates, and 59 failed. Here also, while there were few papers of outstanding merit, the general level was satisfactory.

Précis-writing.—The number of candidates in this subject was 138. In Stage III there were 47, of whom 8 obtained first-class certificates, 24 obtained second-class certificates, and 15 failed. The standard of attainment was about the same as in past years. The passage set was a good test of judgment of the relative importance of the incidents described, and most candidates acquitted themselves fairly well in this respect, although, as usual, a number fell into the mistake of entering into too much unnecessary detail in some points.

In Stage II there were 91 candidates, of whom 12 obtained first-class certificates, 49 obtained second-class certificates, and 30 failed. Here, too, the general average was about the same as in 1926; there were fewer first-classes, but also fewer failures.

Commercial Law.—The total number of candidates in this subject was 517. In Stage III there were 185, of whom 59 obtained first-class certificates, 96 obtained second-class certificates, and 30 failed. The standard in the majority of the papers worked in April was very good, but those worked in May were not as a rule of the quality expected of advanced candidates. Knowledge of legal principles was inexact, and there was a great deal of irrelevancy.

In Stage II there were 332 candidates, of whom 129 obtained first-class certificates, 160 obtained second-class certificates, and 43 failed. While there were not so many excellent papers as usual, there were few really bad ones. The Examiner comments on the tendency of candidates who do not know the

correct answer to invent one, and he also mentions more than once that some answers could not be read owing to the illegibility of the handwriting.

Company Law.—The number of candidates shows a slight increase, as compared with last year, the total being 344 as against 318. In Stage III, of 132 candidates, 55 obtained first-class certificates, 67 obtained second-class certificates, and 10 failed. These were a very good set of candidates, and, with few exceptions, showed a sound general knowledge of the principles of Company Law. The Examiner gathers that teachers and candidates have read previous Examiners' reports, for a number of mistakes to which attention has several times been drawn have at last disappeared.

In Stage II, of 212 candidates 94 obtained first-class certificates, 86 obtained second-class certificates, and 32 failed. Most of the papers showed a good knowledge of general principles, but many candidates were weak as regards winding-up and procedure at company meetings. The papers worked in July were all good, there being no failures.

Accounting.—The number of candidates in this subject was 516, of whom 46 obtained first-class certificates, 248 obtained second-class certificates, and 22 failed. The best papers, as usual, were excellent, but most candidates were weak in answering questions dealing with executorship and income tax.

Banking.—Only 16 candidates entered for this examination, of whom 3 obtained first-class certificates, 9 obtained second-class certificates, and 4 failed. The theoretical work, was, on the whole, good, but there were no papers of outstanding merit.

Costing.—The number of candidates in this important subject shows a gratifying increase, being 117, as compared with 73 last year. Eight candidates obtained first-class certificates, 62 obtained second-class certificates, and 47 failed.

Foreign Exchange.—Thirty-two candidates entered for this subject, 16 in Stage III and 16 in Stage II. Of the former 9 obtained first-class certificates, 6 obtained second-class certificates, and 1 failed. The high proportion of first-classes is very satisfactory. In Stage II, 7 obtained first-class certificates, 8 obtained second-class certificates, and 1 failed. There appeared to be a considerable amount of confusion between travellers' letters of credit and various other means of obtaining money when away from home.

Commerce.—The hope expressed in last year's report that the popularity of this subject would continue to grow has been to a certain extent realised. In 1925 the number of candidates was 1,223; in 1926 it was 1,717, and in

1927 it was 2,161. The increase is no doubt due in some measure to the abolition of the examination in "Commercial Correspondence," which was a popular if not very scientific subject. Stage III was taken by 237 candidates, of whom 22 obtained first-class certificates, 149 obtained second-class certificates, and 66 failed. As the figures indicate, if the number of very good scripts was few, there was also an absence of very weak papers, and the Examiner reports that while candidates were often able to answer correctly where facts and information were concerned, they showed considerable weakness when points demanding judgment and the expression of opinion were under discussion. It is satisfactory to learn that the papers worked in May left the impression of a distinct improvement on the work of last year.

In Stage II there were 791 candidates, of whom 259 obtained first-class certificates, 375 obtained second-class certificates, and 157 failed. The Examiner said that the work, on the whole, was "exceedingly satisfactory," and again gives the impression of a decided improvement as compared with previous examinations. "Some of the best scripts," he writes, "reached a very high standard."

In Stage I, of 1,133 candidates, 173 passed with credit, 598 passed, and 362 failed. The papers worked in April were generally weak; those worked in May were distinctly better, while those worked in July were "exceedingly good, there being only 14 failures out of a total of 170, and 45 passes with credit."

Railway Law and Practice.—There were 55 candidates in this subject, as compared with 44 last year. Of these 7 obtained first-class certificates, 36 obtained second-class certificates, and 12 failed. The Examiner notes that the chief weakness among students is to forget that they are answering questions of law, and to allow questions of commercial policy to overshadow the legal position.

Railway Economics.—There were only 7 candidates in this subject, as against 17 last year. Of these 2 obtained first-class certificates, 4 obtained second-class certificates, and 1 failed.

Shipping Law and Practice.—In spite of the size and importance of the shipping industry of this country, the entries in this subject are surprisingly small. Indeed, this year there has been a falling off, the number of candidates being only 25, as compared with 38 last year. Of those, 3 obtained first-class certificates, 15 obtained second-class certificates, and 7 failed. Here, again, as in *Railway Law and Practice* candidates showed weakness in making a clear statement of law upon a given point.

Stock Exchange Law and Practice.—The number of candidates entering for this subject, 48, shows a slight increase as compared with that of last year,

36; but in view of the large staffs employed in connexion with the Stock Exchange, it is to be hoped that the figures will grow considerably. In Stage III there were 15 candidates, of whom 4 obtained first-class certificates, 9 obtained second-class certificates, and 2 failed. The Examiner reports that the chief cause for complaint was undue verbosity, some candidates having written pages in answer to questions that had not been asked. In Stage II, of 33 candidates, 12 obtained first-class certificates, 17 obtained second-class certificates, and 4 failed. In several cases the English of the students was poor, and there was too much ignorance on the subjects of stamp duties and contract notes.

Advertising and Salesmanship.—62 candidates took this subject, of whom 32 obtained first-class certificates, 24 obtained second-class certificates, and 6 failed. The Examiner complains that the literary standard was very low, and some candidates showed an ignorance of grammar and spelling that is quite unpardonable in an advanced student.

MODERN LANGUAGES.

French.—The total number of candidates in this subject was 5,437. In Stage III there were 436, of whom 111 obtained first-class certificates, 226 obtained second-class certificates, and 99 failed. The standard of excellence in this Stage appears to be very high, and the Examiner, who has had many years' experience of University work, is of opinion that the level reached here is as good as that in the final examinations of our Universities. We now possess a large number of capable teachers in this country, who have been specially trained for the task of teaching French, and most of whom have had the advantage of residence abroad. The result is that French, from having been amongst the most neglected, has come to be about the best taught subject in our schools.

In Stage II, of 1,869 candidates, 468 obtained first-class certificates, 843 obtained second-class certificates, and 558 failed. A certain number of candidates who had been trained on the literary side, lured by the apparent easiness of the commercial passages, selected the latter, only to show that they had no proper understanding of business technicalities. This tactical mistake accounted for a number of failures. Both in this Stage and in Stage III a number of very excellent free compositions were handed in.

In Stage I there were 3,132 candidates, of whom 197 passed with credit, 2,089 passed, and 846 failed. A certain number of these were evidently below any reasonable examination standard, and wrote rubbish such as "my mother shot herself with a novel on the old sofa" or "she undressed herself with a drink." Again, the Examiner comments on the fact that while some candidates were able to answer the questions on the irregular verbs quite well, they made impossible blunders when they came to apply their knowledge.

German.—The number of candidates, 583, shows a considerable increase as compared with the total of last year, 410. In Stage III, of 59 candidates 14 obtained first-class certificates, 28 obtained second-class certificates, and 17 failed. The general level of the work was good, and many of the essays and commercial letters were excellent. In Stage II there were 181 candidates, of whom 49 obtained first-class certificates, 77 obtained second-class certificates, and 55 failed. While a certain number of scripts were really good the majority were marred by weakness in vocabulary and word-analysis and “a wanton disregard of syntax.” The importance of a sound knowledge of grammar and syntax in any language cannot be insisted upon too strongly.

In Stage I there were 343 candidates, of whom 30 passed with credit, 173 passed, and 140 failed. The papers worked in April showed much better results than usual. The formal grammar and compositions were really good, and the translations into German very fair. The June and July scripts, however, were disappointing, with the exception of those worked at two or three big centres.

Italian.—Ninety-two candidates entered in this subject. In Stage III there were 8, of whom 5 obtained first-class certificates, and 3 second-class certificates. The papers were good, and there were no failures. In Stage II, of 36 candidates, 5 obtained first-class certificates, 24 obtained second-class certificates, and 7 failed. The work generally showed careful preparation on the part of the students. In Stage I there were 48 candidates of whom 4 passed with credit, 34 passed and 10 failed. The Examiner reports a definite advance on the standard of the last few years.

Spanish.—This continues to be the second most popular modern language, the total number of entries this year being 802. In Stage III, of 109 candidates, 16 obtained first-class certificates, 72 obtained second-class certificates, and 21 failed. The best work was done in essay-writing, and obviously there has been wider reading of modern Spanish literature than in former years. The oral work was in some cases very poor, and showed that candidates ought to have more practice in conversation.

In Stage II, of 255 candidates, 22 obtained first-class certificates, 203 obtained second-class certificates, and 30 failed. The Examiner comments very favourably on the work of all the first-class candidates.

In Stage I, of 438 candidates, 16 passed with credit, 379 passed, and 43 failed. On the whole the work showed improvement, as compared with former years, but the translations into Spanish were often marred with inaccuracies, verbs and genders being the most fruitful source of trouble.

Russian.—Seventeen candidates entered for this subject. In Stage III there were 4, of whom 1 obtained a first-class certificate, 2 obtained second-class certificates, and 1 failed. The best paper was of exceedingly high merit.

In Stage II there were 7 candidates, of whom 4 obtained first-class certificates, and 3 obtained second-class certificates. Some of the essays were very good, and the average marks were higher than in any previous year. In Stage I there were 6 candidates, of whom 1 passed with credit, 4 passed, and 1 failed. There was a marked improvement in the answers to the grammar questions, but more attention should be given to composition.

Portuguese.—There were 13 entries for this subject. In Stage III, of 4 candidates, 1 obtained a first-class certificate, and 3 obtained second-class certificates. In Stage II, of 9 candidates, 3 obtained first-class certificates, and 6 obtained second-class certificates. There were no failures in either Stage.

ORAL EXAMINATIONS.

The results of the Oral Test which is now compulsory for all candidates in the Advanced Stage of French, German, Spanish, and Italian were again well above the average; although there were 27 fewer candidates than in 1926, there were 26 less failures this year. An important part of the Oral Test is the taking down of a passage dictated in the foreign language by the examiner, and in the past this has been a source of great weakness with many candidates. It is gratifying to be able to state that the examiners now report a very great improvement in this branch of the examination.

ORAL EXAMINATIONS HELD DURING 1927.

Subject.	No. of Examina- tion Centres.	No. of Exami- ners.	No. of Candi- dates. examined.	Passed with Dis- tinction.	Passed.	Failed.
French ...	48	33	465	134	265	66
German ...	15	15	54	16	34	4
Spanish ...	18	16	101	20	67	14
Italian ...	5	4	9	5	3	1
	86	68	629	175	369	85

GROUP CERTIFICATES IN COMMERCIAL SUBJECTS.

The increase, noted in last year's report in the number of candidates entered from Higher Elementary Schools, and also the new Central Day Schools set up under various Education Authorities, has been well maintained. Most of

these candidates take a number of subjects qualifying for the Group Certificate in Elementary Commercial Subjects. To gain this special certificate candidates must pass in Arithmetic, English and two other subjects within three consecutive years, but it is satisfactory to find that many pupils from Day Schools pass in the necessary subjects in one year. In view of the fact that a fairly high standard is maintained in the Elementary Stage (it is by no means a first year's examination), the results at these Schools give evidence of really excellent preparation.

GROUP CERTIFICATE PRIZES.

In order to encourage students to take up groups of subjects, the Council decided in 1924 to offer £200 in prizes for candidates who completed group certificates in Commercial Subjects in the Advanced and Intermediate Stages in 1925; the prizes were offered again in 1926 and were won by candidates who all obtained a high percentage of marks in the respective subjects.

In 1927, fourteen prizes of £10 each were offered in the Advanced Stage and twelve prizes of £5 each in the Intermediate Stage.

The qualification for Group Certificates is as follows :—

Advanced Stage.—Candidates must pass in the following four subjects in the Advanced Stage in three consecutive years: Book-keeping, Commerce, Economic Theory, and any one of the remaining subjects (other than Shorthand, Typewriting, and Précis-Writing), in which an Examination in the Advanced Stage is held.

Intermediate Stage.—Candidates must pass in the following four subjects, either in the Advanced or Intermediate Stage, in three consecutive years: Arithmetic, Book-keeping, Commerce, and any one of the other subjects in which an Examination in the Intermediate Stage is held. (For the purpose of this Certificate Shorthand and Typewriting are considered as one subject).

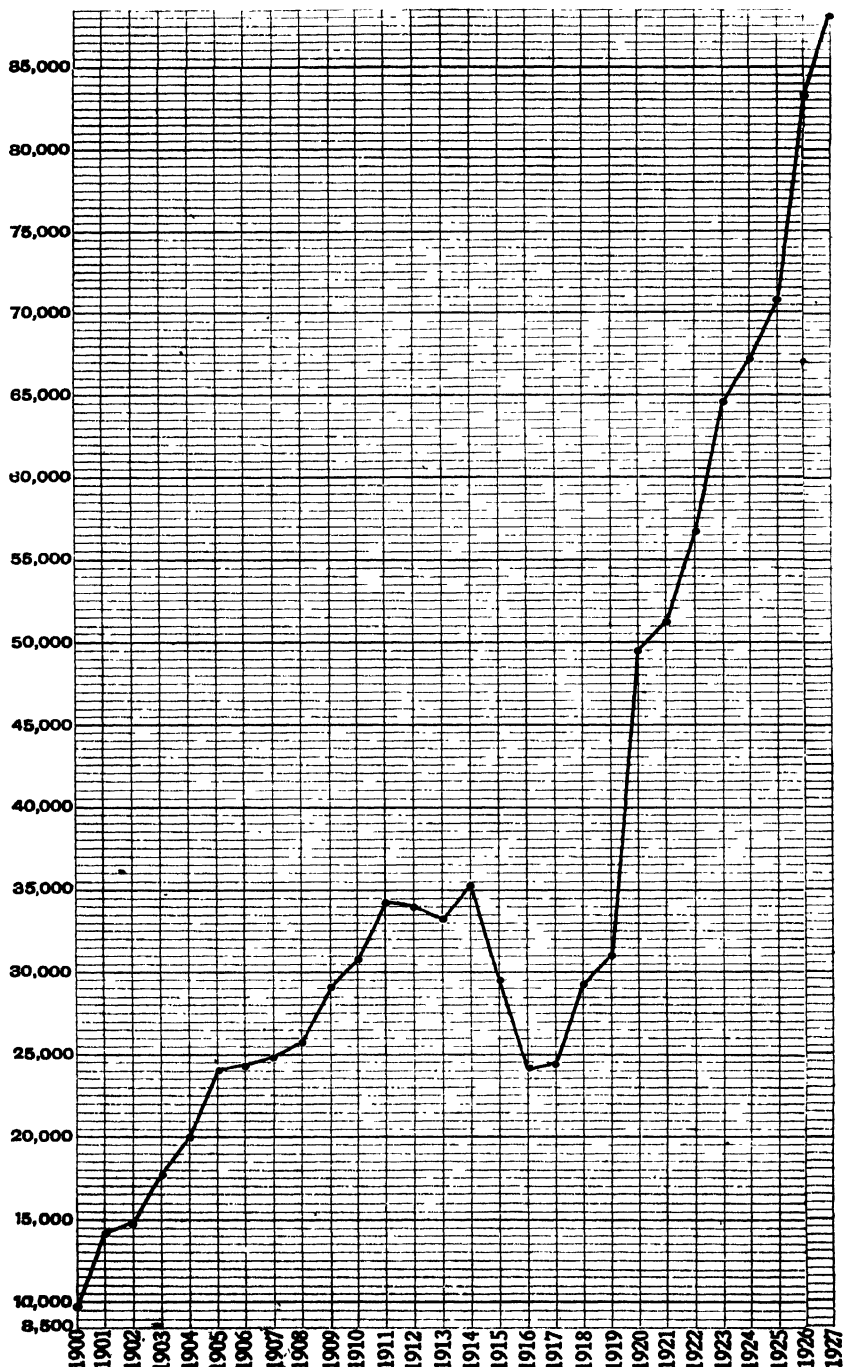
It is not yet known how many applications there will be for these group prizes in the current year, but it is hoped to publish the names of the prize winners very shortly.

The thanks of the Council are once more accorded to the Court of the Clothworkers' Company, who have generously renewed their grant of £40 towards providing medals in all the subjects of examination where the work of candidates attains a sufficiently high standard. There is no doubt that there is very keen competition for these medals, and that they have done much to maintain or raise the level of excellence in the papers worked.

SCHOOL AND JUNIOR SCHOOL CERTIFICATE EXAMINATIONS.

A new series of Examinations has been instituted this year, specially designed for candidates from Day Schools. It was held for the first time last July.

DIAGRAM SHOWING NUMBERS OF PAPERS WORKED IN THE ROYAL SOCIETY OF ARTS EXAMINATIONS, 1900-1927.



DETAILS OF THE 1927 EXAMINATIONS.

SUBJECTS.	STAGE III.—ADVANCED.				STAGE II.—INTERMEDIATE.				STAGE I.—ELEMENTARY.				Total number of Papers worked in all Stages.	
	Papers worked.	Indices Certificate rates.	Not Passed.	Papers worked.	Indices Certificate rates.	Indices Certificate rates.	Not Passed.	Papers worked.	Passed with credit.	Passed.	Not Passed.	1927	1926	
Arithmetic ..	322	72	133	2,649	603	994	1,052	7,562	964	4,129	2,469	10,533	10,773	
English ..	351	23	197	2,022	121	1,327	574	4,472	110	2,540	1,822	6,845	7,189	
Book-keeping ..	3,860	433	1,680	8,727	1,945	4,730	2,052	10,419	716	4,970	4,733	23,006	23,467	
Economic Geography ..	61	9	33	296	41	176	79	748	76	443	229	1,105	1,295	
Shorthand ..	1,502	135	547	820	799	3,208	3,504	7,115	2,869	2,209	2,037	16,128	17,081	
Typewriting ..	878	245	475	158	1	54	7	32	15	80	15	186	159	
Economic and Social History ..	21	7	13	288	29	200	59	111	16	80	15	515	555	
Economic Theory ..	227	37	128	62	15	91	30	—	—	—	—	138	150	
Précis-writing ..	47	8	24	15	12	49	30	—	—	—	—	—	3,909	
Commercial Correspondence ..	—	—	—	—	—	—	—	—	—	—	—	—	517	
Commercial Law ..	185	59	56	332	129	160	43	—	—	—	—	517	577	
Company Law ..	132	55	67	10	94	86	32	—	—	—	—	344	318	
Accounting ..	516	46	248	222	—	—	—	—	—	—	—	516	555	
Banking ..	16	3	9	—	—	—	—	—	—	—	—	16	25	
Costing ..	117	8	62	47	—	—	—	—	—	—	—	117	73	
Foreign Exchange ..	16	9	6	16	7	8	1	—	—	—	—	32	28	
Commerce ..	237	22	149	66	259	375	157	1,133	173	598	362	2,161	1,717	
Railway Law and Practice ..	55	7	36	12	—	—	—	—	—	—	—	55	44	
Railway Economics ..	7	2	4	1	—	—	—	—	—	—	—	7	17	
Shipping Law and Practice ..	25	3	15	7	—	—	—	—	—	—	—	25	38	
Stock Exchange Law & Practice ..	15	4	9	2	12	17	4	—	—	—	—	48	36	
Insurance Law and Practice ..	—	—	—	—	—	—	—	—	—	—	—	—	10	
Advertising and Salesmanship ..	62	32	24	6	—	—	—	—	—	—	—	62	40	
French ..	436	111	226	99	468	843	558	3,132	197	2,089	846	5,437	5,747	
German ..	59	14	28	17	49	77	55	343	30	173	140	563	410	
Italian ..	8	5	3	36	5	24	7	48	4	34	10	92	88	
Spanish ..	109	16	72	21	22	203	50	438	16	379	43	802	707	
Russian ..	4	1	2	1	4	3	—	6	1	4	1	17	18	
Portuguese ..	4	1	3	9	3	6	—	—	—	—	—	13	8	
Swedish ..	—	—	—	—	—	—	—	—	—	—	—	—	5	
Totals, 1927 ..	9,272	1,367	4,289	28,733	5,618	14,514	8,601	40,137	6,054	20,391	13,692	78,142	—	
" 1926 ..	8,954	1,158	4,050	29,867	5,002	13,897	10,368	44,425	—	29,264	15,161	—	83,246	

In addition to the figures given above, 7,468 papers in the Elementary Stage were worked in May—June at the Group Course Examination for London County Council Junior Commercial and Technical Institutes, and 2,478 papers were worked at the Junior School and School Commercial Certificate Examinations held in July. The grand total of papers worked in 1927 is, therefore, 88,088.

The subjects of examination are :—

COMPULSORY SUBJECTS: Arithmetic, Book-keeping, Economic Geography, English, History.

ELECTIVE SUBJECTS: French, German, Spanish, Italian (not more than two foreign languages may be taken), Commerce, Shorthand, Typewriting (School Commercial Certificate only), Mathematics and Natural Science (Physics, Chemistry, and Botany). Candidates must take not less than two and not more than four of these subjects.

The total number of candidates was 312. Of these 43 entered for the School Commercial Certificate. One obtained a first-class full certificate, and 16 obtained second-class full certificates. For the Junior School Commercial Certificate there were 269 candidates; 36 obtained full first-class certificates, and 124 obtained full second-class certificates. Candidates who failed to obtain full certificates received certificates for the subjects in which they passed.

EXAMINATIONS FOR LONDON COUNTY COUNCIL JUNIOR COMMERCIAL AND JUNIOR TECHNICAL INSTITUTES.

At the request of the Education Committee of the London County Council, the Society undertook this year to hold course examinations for (a) students in L.C.C. Junior Commercial Schools, and (b) students in L.C.C. Junior Technical Schools.

The total number of entries from both classes of Schools was 2,745. There were 1,531 candidates from the Junior Commercial Schools, of whom 729 obtained group certificates; and 895 from the Junior Technical Schools, of whom 497 obtained group certificates.

OBITUARY.

SIR WILLIAM GALLOWAY, D.Sc., F.G.S.—Sir William Galloway, who died at Cardiff on November 2nd, was the son of the late William Galloway, J.P., of Paisley. He was educated, firstly, at a private school and afterwards at the University of Giessen, the Bergakademie, Freiberg, and University College, London. At a later date the honorary degree of D.Sc. was conferred upon him by the University of Wales. His work as one of H.M. Inspectors of Mines in the West of Scotland and South Wales gave him a thorough knowledge of coal mining conditions, and he was the inventor of the coal-dust theory of colliery explosions. He investigated the cause and mode of such explosions, and first suggested, in 1898, the use of stone-dust as a preventive, a method which was universally adopted in 1906, and has been the means of saving a large number of lives. He also conducted a series of experiments with various kinds of explosives fired into mixtures of air gas and coal-dust, for the Royal Commission on Accidents in Mines. For these and other similar services, such as the determination of the relation between the height of fire-damp cap and the proportion of fire-damp in the air in mines, and the invention of the guides for sinking pits, he was presented with a Gold Medal and illuminated album by the

South Wales Institute of Engineers, with the Medal of the Institution of Mining Engineers, and, in 1908, with the Shaw Gold Medal under the Shaw Trust by the Royal Society of Arts, "in recognition of his valuable researches into the action of coal dust in colliery explosions, the outcome of which researches has been the provision of means by which the risk of such accidents is materially diminished, and a consequent great saving of human life is effected."

Sir William Galloway, who received the honour of knighthood in 1924, was formerly Professor of Mining in the University College of South Wales and Monmouthshire and occupied at various times a number of important official positions connected with mining engineering. He was the author of twenty-one papers—four in collaboration with Mr. R. H. Scott, F.R.S.—on researches into the causes of colliery explosions, eight of these being read before and published by the Royal Society, as well as of a large number of other papers mainly on subjects connected with mining. Sir William had been a member of the Society for more than a quarter of a century, having been elected in 1900.

GENERAL NOTE.

REPORTS OF THE BRITISH COTTON GROWING ASSOCIATION.—The British Cotton Growing Association has recently issued two reports, price 1s. each, on (1) the Union of South Africa, and (2) Northern and Southern Rhodesia, and Nyasaland, as sources for increasing our supplies of raw cotton. The reports embody the latest information on the present position and prospects of cotton growing in these territories, and are the outcome of a tour of inspection of the cotton-growing areas carried out in the spring and early summer of this year by Sir William H. Himbury and Mr. H. Astley-Bell on behalf of the British Cotton Growing Association.

CONTRIBUTIONS TO THE READING ROOM.

The Council acknowledge, with thanks to the Proprietors, the receipt of the following Transactions of Societies and other Periodicals :—

TRANSACTIONS, ETC.

African Society, Journal.
American Academy of Arts and Sciences,
Proceedings.
American Chemical Society, Journal.
American Institute of Electrical Engineers,
Transactions.
American Leather Chemists' Association,
Journal.
American Philosophical Society, Proceedings
and Transactions.
Architectural Association, Journal.
Auctioneers' and Estate Agents' Institute,
Journal.

Australasian Association for the Advance-
ment of Science, Report.
Bath and West of England Society, Journal.
British Cold Storage and Ice Association,
Proceedings.
British Dental Association, Journal.
British Science Guild, Journal.
British Waterworks Association, Official
Circular.
Canada, Royal Society, Proceedings and
Transactions.
Central Chamber of Agriculture, Journal.
Chartered Institute of Patent Agents, Trans-
actions.
Chemical Society, Journal.

- Chicago, Field Museum of Natural History, Publications.
- Cleveland, Institution of Engineers, Proceedings.
- Commonwealth Institute of Science and Industry, Bulletin.
- East India Association, Journal.
- Farmers' Club, Journal.
- Franklin Institute, Journal.
- Geneva, Société des Arts, La Revue Polytechnique.
- Geological Society, Quarterly Journal.
- Geologists' Association, Proceedings.
- Glasgow, Royal Philosophical Society, Proceedings.
- Imperial Arts League, Journal.
- Imperial Institute, Bulletin.
- India, Geological Survey, Memoirs and Palæontologia Indica.
- Indian Meteorological Department, Monthly Weather Review.
- Institute of Bankers, Journal.
- Institute of Brewing, Journal.
- Institute of British Carriage and Automobile Manufacturers, Journal.
- Institute of Chemistry, Journal and Proceedings.
- Institute of Metals, Journal.
- Institute of Wireless Technology, Journal.
- Institution of Automobile Engineers, Proceedings.
- Institution of Civil Engineers, Minutes of Proceedings.
- Institution of Civil Engineers of Ireland, Transactions.
- Institution of Electrical Engineers, Journal.
- Institution of Engineers and Shipbuilders in Scotland, Transactions.
- Institution of Gas Engineers, Transactions.
- Institution of Mechanical Engineers, Journal and Proceedings.
- Institution of Mining and Metallurgy, Transactions.
- Institution of Municipal and County Engineers, Journal.
- Institution of Naval Architects, Transactions.
- Institution of Petroleum Technologists Journal.
- Iron and Steel Institute, Journal.
- Japan Society, Transactions and Proceedings.
- Johannesburg, Chemical, Metallurgical and Mining Society, Journal.
- Junior Institution of Engineers, Record of Transactions.
- Kyoto, Imperial University, Memoirs of the College of Science.
- Linnean Society, Journal.
- Liverpool Engineering Society, Transactions.
- London Society, Journal.
- Manchester Literary and Philosophical Society, Memoirs and Proceedings.
- , Municipal School of Technology, Journal.
- , Textile Institute, Journal.
- Michigan Academy of Science, Reports.
- Milan, Associazione Elettrotecnica Italiana, Atti.
- National Physical Laboratory, Collected Researches.
- New South Wales, Royal Society, Journal and Proceedings.
- New York Academy of Sciences, Annals and Memoirs.
- New Zealand Board of Science and Art, Journal.
- North-East Coast Institution of Engineers and Shipbuilders, Transactions.
- Norwich, Operative Brewers' Guild, Journal.
- Nova Scotian Institute of Science, Transactions.
- Oil and Colour Chemists' Association, Journal.
- Paris, Société d'Encouragement pour l'Industrie Nationale, Bulletin.
- , Société de Géographie Commerciale, Revue.
- , Société des Ingénieurs Civils, Mémoires.
- , Société Internationale des Electriciens, Bulletin.
- , Société Nationale d'Acclimatation de France, Bulletin.
- Patent Office, Abridgments of Specifications.
- Pennsylvania (Western), Engineers' Society of, Proceedings.
- Philadelphia, Academy of Natural Sciences, Proceedings.
- Physical Society, Proceedings.
- Quekett Microscopical Club, Journal.
- Royal Aeronautical Society, Journal.
- Royal Agricultural Society, Journal.

Royal Asiatic Society, Journal.
 Royal Astronomical Society, Memoirs.
 Royal Canadian Institute, Transactions.
 Royal Cornwall Polytechnic Society, Annual Report.
 Royal Dublin Society, Proceedings and Transactions.
 Royal Horticultural Society, Journal.
 Royal Institute of British Architects, Journal.
 Royal Institution of Great Britain, Proceedings.
 Royal Irish Academy, Transactions and Proceedings.
 Royal Meteorological Society, Quarterly Journal and Record.
 Royal National Life-boat Institution, "The Life-boat" and Annual Report.
 Royal Sanitary Institute, Journal.
 Royal Society, Philosophical Transactions and Proceedings.
 Royal Society of Edinburgh, Transactions and Proceedings.
 Royal Statistical Society, Journal.
 Smithsonian Institution, Report and Publications.
 Society of Antiquaries, Archæologia and Journal.
 Society of Chemical Industry, Journal.
 Society of Dyers and Colourists, Journal.
 Society of Engineers, Transactions.
 South African Association for the Advancement of Science, Report.
 South Wales Institute of Engineers, Proceedings.
 Tokyo, Imperial University, Journal of the College of Science.
 Tramways and Light Railways Association, Journal.
 United States Department of Commerce, Reports.
 Victoria Institute, Journal of the Transactions.
 Washington, National Academy of Sciences, Proceedings.
 Wisconsin Academy of Sciences, Transactions.

JOURNALS.

Weekly.

Amateur Photographer.
 American Machinist.
 Board of Trade Journal.
 Bookseller.
 Bradstreet's.
 British Journal of Photography.
 Builder.
 Cabinet Maker.
 Chamber of Commerce Journal.
 Chemical Age.
 Chemical News.
 Chemist and Druggist.
 Colliery Guardian.
 Contract Journal.
 Contractors' Record.
 Education.
 Electrical Industries.
 Electrical Review.
 Electrical Times.
 Electricity.
 Engineer.
 Engineering.
 English and Amateur Mechanics.
 Gardeners' Chronicle.
 Gas Journal.
 Grocer.
 Indian Engineering.
 Iron and Coal Trades Review.
 Journal of Agricultural Research (Washington).
 Lancet.
 Leather.
 London County Council Gazette.
 London Teacher.
 Machinery.
 Machinery Market.
 Mechanical World.
 Mining Journal.
 Model Engineer.
 Motor Transport.
 Musical Standard.
 Nature.
 Near East and India.
 Notes and Queries.
 Oil and Colour Trades Journal.
 Paper Trade Review.
 Pharmaceutical Journal.
 Pitman's Journal.

Produce Markets Review.
Public Opinion.
Pulp and Paper Magazine of Canada.
Saturday Review.
Scientific American.
Shipping World.
Spectator.
Textile Mercury.
Timber News.

Fortnightly.

British Industries.
Dyer and Calico Printer.
Jeweller and Metalworker.
Perak Government Gazette.
Revue du Travail.
Revue Générale des Sciences.
West India Committee Circular.

Monthly.

Analyst.
Architecture
Automobile Engineer.
Brewers' Journal.
British Builder.
British Engineers' Export Journal.
British Trade Journal.
Building.
Bulletin Technique du Bureau Veritas.
Chimie & Industrie.
Civil Engineering.
Cold Storage.
Commercial Art.
Cotton (Atlanta).
Decorator.
Discovery.
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Empire Production and Export.
Engineering and Boiler House Review.
Engineering Journal (Canada).
Engineers and Engineering (Philadelphia).
Export World.
Fuel Economist.
Gas and Oil Power.
Gas Engineer.
Geographical Journal.
Geographical Review (New York).
Horological Journal.
Ice and Cold Storage.
Illuminating Engineer.

Industrial Chemist.
Industrial Management.
International Sugar Journal.
Journal of the Department of Agriculture (Pretoria).
Journal of the Ministry of Agriculture.
Kew Bulletin.
Leather Trades' Review.
Locomotive.
Master Builder.
Meteorological Magazine.
Miller.
Mining Electrical Engineer.
Mining Magazine.
Musical Times.
Mysore Economic Journal.
Norwegian Trade Review.
Oil Engineering and Finance.
Paint and Wallpaper.
Paper Makers' Monthly Journal.
Photographic Journal.
Popular Radio (New York).
Popular Science (New York).
Pottery Gazette.
Propriété Industrielle (Berne).
Science Abstracts.
Scottish Geographical Magazine.
Secretary.
Smith's Dock Monthly.
South African Engineering.
South African Journal of Industries.
Stone Trades Journal.
Studio.
Textile Manufacturer.
Textile Recorder.
Tropical Agriculture.
Tropical Life.
United Empire.
Watchmaker, Jeweller, and Silversmith.
Water and Water Engineering.
World Power.

Quarterly.

Agricultural Journal of India.
Asiatic Review.
Baldwin Locomotives.
Co-partnership.
Edinburgh Review.
Fuel Economy Review.
Industrial Gases.
Quarterly Review.

NEWSPAPERS.

African World.
Ceylon Observer (Overland Edition).
China Express and Telegraph.
Daily Argosy (Demerara).
Englishman (Calcutta).

Home and Colonial Mail.
London Commercial Record.
Madras Weekly Mail.
Pioneer Mail (Allahabad).
South Africa.
Times of India (Overland Weekly Edition).

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, NOVEMBER 14. Brewing, Institute of, at the Charing Cross Station Hotel, Strand, W.C. 7.45 p.m. Dr. August Fernbach, "Modern Malt Kilns."

Electrical Engineers, Institution of, at Armstrong College, Newcastle-on-Tyne. 7 p.m. Messrs. A. H. Law and J. P. Chittenden, "Higher Steam Pressures and their Application to the Steam Turbine," at Bristol, Mr. A. R. Cooper, "Electrical Equipment of Track on the Underground Railways of London."

Geographical Society, Lowther Lodge, Kensington Gore, W. 5 p.m. Colonel H. S. L. Winterbotham, "The Triangulation of Africa."

Metals, Institute of, at 39, Elmbank Crescent, Glasgow. 7.30 p.m. Mr. A. Logan, "Brass Foundry Practice." Philologie, Sciences et Beaux-Arts, Société Internationale de, 8, Tavistock Street, W.C. 3.30 p.m. Mr. D. Freedman, "The Wisdom of the Ages."

Physics, Institute of, at the Institution of Electrical Engineers, Savoy Place, W.C. 5.30 p.m. Sir William Hardy, "Physics in the Food Industry."

Public Works, Roads and Transport Congress, at the Royal Agricultural Hall, Islington, N. 2.30 p.m. Mr. F. H. Osmond-Smith, "The Advancement of Agriculture."

Surveyors' Institution, 12, Great George Street, S.W. 8 p.m. Mr. E. S. Cox, Presidential Address.

University of London, at the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Prince D. Svyatofolk Mirsky, "The Russian Novel, 1845-1880." (Lecture VI.)

At King's College, Strand, W.C. 5.30 p.m. Rev. C. F. Rogers, "Ecclesiastical Music." (Lecture I.) 5.30 p.m. Dr. H. G. Atkins, "Heine a Hundred Years Ago." (Lecture I.)

At University College, Gower Street, W.C. 5.15 p.m. Dr. E. A. Hauser, "The Colloid Chemistry of the Rubber Industry." (Lecture IV.)

TUESDAY, NOVEMBER 15. Civil Engineers, Institution of, Great George Street, S.W. 6 p.m. Mr. Oscar Faber, "Plastic Yield, Shrinkage and other Problems of Concrete and their Effect on Design."

Electrical Engineers, Institution of, at the Hotel Metropole, Leeds. 7.15 p.m.

At the Milton Hall, Manchester. 7 p.m. Mr. W. McClelland, "The Application of Electricity in Warships."

At the College, Loughborough. 6.45 p.m. Mr. W. Wilson, "Protective Gear."

Photographic Society, 35, Russell Square, W.C. 7 p.m. Kinematograph Group Meeting.

Physiology, London College of, 8, Tavistock Street, W.C. 8.15 p.m. Mme. E. Miriam Leon, "Herbal Remedies."

Public Works, Roads and Transport Congress, at the Royal Agricultural Hall, Islington, N. 11 a.m. and 3 p.m. Dr. J. W. T. Walsh, (a) "Street Lighting regarded as an Illumination Problem." Mr. R. D. Jones, (b) "Street Lighting of London." Mr. R. D. Gauld, "The Future of Light Railways in the British Isles." Mr. F. W. Goodenough, C.B.E., "How the Gas Industry can assist Smoke Abatement."

Royal Institution, 21, Albemarle Street, W. 5.15 p.m. Sir J. H. Parsons, "Light and Sight." (Lecture III.) 9.15 p.m. M. Paul Painlevé, "Les Conceptions Modernes de la Matière et de la Science Classique."

Statistical Society, at the Royal Society of Arts, Adelphi, W.C. 5.15 p.m.

Transport, Institute of, at Savoy Place, W.C. 5.45 p.m. Prof. J. G. Smith, "Transport Rate-making in Theory."

University of London, at the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Sir Bernard Pares, "Russian History to 1861." (Lecture VI.) At King's College, Strand, W.C. 5.30 p.m. Miss Hilda D. Oakeley, "The Philosophy of Personality." (Lecture I.)

At University College, Gower Street, W.C. 5.30 p.m. M. Emile Cannaerts, "L'Œuvre dramatique de Maeterlinck" (in French).

WEDNESDAY, NOVEMBER 16. Academy of Arts, Royal, Burlington House, W. 4 p.m. Dr. A. P. Laurie, "The Theory of Colour and its Application to Painting."

Civil Engineers, Institution of, Great George Street, S.W. 6.30 p.m. (Students' Meeting.) Mr. J. R. B. Griggs, Chairman's Address.

Constructive Birth Control, Society for, at Essex Hall, Strand, W.C. 8 p.m. Mrs. H. Bowes Pease, "A Consideration of the Position of Labour Women and Birth Control."

Electrical Engineers, Institution of, at the Royal Victoria Hotel, Sheffield. 7.30 p.m. Messrs. A. H. Law and J. P. Chittenden, "Higher Steam Pressures and their Application to the Steam Turbine."

Engineering Inspection, Institution of. Presidential Address.

Geological Society, Burlington House, W. 5.30 p.m. Messrs. Lane, Spath, Cox, and Miss Muir-Wood, "The Belemnite-Marls of Charmouth: a Series in the Lias of the Dorset Coast."

Mechanical Engineers, Institution of, at Bristol. Sir William H. Bragg, "Application of X-Rays to the Study of the Crystalline Structure of Materials." (Thomas Hawksley Lecture.)

Meteorological Society, Royal, 49, Cromwell Road, S.W. 5 p.m. 1. Dr. C. E. P. Brooks, "The Influence of Forests on Rainfall and Run-off." 2. Mr. C. K. M. Douglas, "The Secondary Depression on the night of January 28-29, 1927." 3. Dr. E. Kidson, "The Circulation of the Atmosphere over Melbourne."

Public Health, Royal Institute of, 37, Russell Square, W.C. 4 p.m. Dr. R. Stenhouse Williams, "The Milk Supply—What shall our Policy be?"

Public Works, Roads and Transport Congress, at the Royal Agricultural Hall, Islington, N. 11 a.m. and 2.30 p.m. Mr. B. Price Davies, (a) "Organisation of Highways Work." Mr. R. O. Gooby, (b) "Rural Simplicity." Mr. C. S. Chettoe, (a) "The Design of Deep Culverts." Prof. E. R. Matthews, (b) "Design and Construction of Reinforced Concrete Conduits, Sewers and Aqueducts."

University of London, at the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Dr. Otakar Vocadlo, "English and American Influences in Czech Literature." (Lecture II.)

At King's College, Strand, W.C. 5.30 p.m. The Very Rev. the Dean of Salisbury, "The Mystery Religions." (Lecture II.)

5.30 p.m. Mr. W. Valentine Ball, "The Enforcement of Foreign Judgments."

5.30 p.m. Dr. Dorothy Brock, "Secondary Education: (3) The Girls' School."

At the London School of Economics, Houghton Street, Aldwych, W.C. 6 p.m. Mr. J. G. Sargeant, Demonstration of the Barlock Typewriter.

At University College, Gower Street, W.C. 3 p.m.

Dr. Pelizzi, "Dante in alcuni giudizi contemporanei" (in Italian). (Lecture III.)

5.15 p.m. Dr. E. A. Hauser, "The Colloid Chemistry of the Rubber Industry." (Lecture V.)

5.30 p.m. Mr. Philip B. James, "The Decoration of Bookbindings."

5.30 p.m. Mr. I. C. Gromdahl, "Regions and Place-Names in Norway." (Lecture II.)

THURSDAY, NOVEMBER 17. Academy of Arts, Royal, Burlington House, W. 4 p.m. Dr. A. P. Laurie, "Early Methods of Oil Painting."

Aeronautical Society, at the Royal Society of Arts, Adelphi, W.C. 6.30 p.m. Mr. R. K. Pierson, "The Use of the Wind Tunnel in the Prediction of Aeroplane Performance."

Chemical Society, Burlington House. 8 p.m. Mr. B. Cavanagh, "Differential Potentiometric Titration. Part I.: Simple Method." Mr. B. Cavanagh, "Differential Potentiometric Titration. Part II.: Refined Method." Miss F. M. Hamer, "A General Method for the Preparation of Carbocyanine Dyes."

Child-Study Society, at 99, Buckingham Palace Road, S.W.1. 6 p.m. Mr. T. Raymont, "Education in America."

Electrical Engineers, Institution of, Savoy Place, Victoria Embankment, W.C. 6 p.m. Mr. B. S. Cohen, "Apparatus Standards of Telephonic Transmission and the Technique of Testing Microphones and Receivers."

Linnean Society, Burlington House, W. 5 p.m.

L.C.C. The Geffrye Museum, Kingsland Road, Shore-ditch, E. 7.30 p.m. Mr. C. H. B. Quennell, "English Houses and Furniture of the Middle Ages."

Mechanical Engineers, Institution of, at Birmingham. Mr. Ernest McKie, "Boiler House Economy."

At Manchester. Sir William H. Bragg, "Application of X-Rays to the Study of the Crystalline Structure of Materials." (Thomas Hawksley Lecture.)

Metals, Institute of, at the Engineers' Club, Waterloo Street, Birmingham. 7 p.m. Discussion on "Annealing."

North-East Coast Institution of Engineers and Ship-builders, at the Mining Institute, Newcastle-upon-Tyne. 6 p.m. Mr. S. G. Visker, "The Application of High Pressures to the Reciprocating Marine Steam Engine."

Public Works, Roads and Transport Congress, at the Royal Agricultural Hall, Islington, N. 11 a.m. and 2.30 p.m. Mr. F. H. Heald, (a) "Rivers Pollution Prevention." Mr. A. Bebbington, (b) "The Law of Rivers Pollution Prevention." Mr. T. P. Francis, (c) "Colloids." Mr. A. H. Parsons and Mr. H. Wilson, (d) "The Solution in Sewage of Oxygen from Diffused Air." Mr. F. R. O'Shaughnessy, assisted by Mr. C. H. Hewitt and Mr. A. S. Miller, (e) "Some Methods of Analysis of Sewage and Effluents."

2.30 p.m. Prof. Dr. J. W. Gregory, (s) "Water Divining." Mr. F. J. Alban, (b) "The Economics of Water Supply," Mr. D. F. Worker, (c) "Rural Water Supplies."

3 p.m. Mr. J. H. Garner, (a) "Small Sewage Works" Mr. F. C. Temple, (b) "First Principles in Sewage Disposal."

Royal Institution, 21, Albemarle Street, W. 5.15 p.m. Dr. R. E. M. Wheeler, "London Before the Norman Conquest."

Tropical Medicine and Hygiene, Royal Society of, at the London School of Hygiene and Tropical Medicine, Endsleigh Gardens, Euston Road, 8.15 p.m. Laboratory Meeting.

University of London, at Bedford College for Women, Regent's Park, N.W. 4.15 p.m. Prof. Eccles,

"Voltaire: les meilleurs moments et les plus belles.

pages" (in French). (Lecture VII.)

At King's College, Strand, W.C. 5.15 p.m. Rev.

Norman Sykes, "Benjamin Hoadly."

5.30 p.m. Rev. C. F. Rogers, "Welsh Hymn Tunes."

At University College, Gower Street, W.C. 5.15 p.m. Prof. de Montmorency, "Customary Law in the British Empire." (Lecture III.)

5.30 p.m. Dr. A. M. Bassani, "Di alcuni poeti dell'Ottocento" (in Italian).

5.30 p.m. Miss E. Jeffries Davis, "London Place-Names." (Lecture II.)

At the Victoria and Albert Museum, South Kensington, S.W. 5.30 p.m. Mr. J. A. Knowles, "The Mediaeval Glass-Painters' Craft."

FRIDAY, NOVEMBER 18. Academy of Arts, Royal, Burlington House, W. 4 p.m. Dr. A. P. Laurie, "Painting Media: Oils, Varnishes, and Tempera."

British Electrical Development Association, at the Royal Society of Arts, Adelphi, W.C. 7.30 p.m.

Chemical Industry, Society of, at Burlington House, W. — p.m. Mr. A. J. Broughall, "Some Modern Methods of Recovery of Lubricating Oils."

Dyers and Colourists, Society of, at Milton Hall, Deansgate, Manchester. 7.30 p.m. Mr. L. G. Lawrie, "The Microscopic Investigation of Artificial Silk Fibres."

London Society, at the Royal Society of Arts, Adelphi, W.C. 5 p.m.

Mechanical Engineers, Institution of, Storey's Gate, St. James's Park, S.W. 7 p.m. Mr. Hal Gutteridge, "Modern Portland Cement Plant."

Medical Officers of Health, Society of, 1, Upper Montague Street, W.C. 5 p.m. Dr. J. J. Buchan, Sir Oscar Warburg, and Col. F. E. Fremantle, "Health Aspects of the Factories Bill."

Philologie, Sciences et Beaux-Arts, Société Internationale de, 8, Tavistock Street, W.C. 8.15 p.m. Mr. G. S. Dara "The Sikhs."

Photographic Society, 35, Russell Square, W.C. 7 p.m. Mr. A. Knapp, "The Graphic Representation of a Third Dimension."

Public Works, Roads and Transport Congress, at the Royal Agricultural Hall, Islington, N. 11 a.m. and 3 p.m. Mr. H. Marsh, (a) "Present-day Implications of Local Ownership of Transport Undertakings." Mr. B. Price Davies, (b) "Costing for Public Works and Buildings."

3 p.m. Mr. E. J. McKaig, (a) "Coast Erosion and Defence." Mr. S. W. Mobbs, (b) "Lowestoft New Sea Defences." Lt.-Col. J. A. A. Pickard, "Road Accidents—Frequency, Cause and Prevention"

Transport, Institute of, at the Lime Street Station Hotel, Liverpool. 6.30 p.m. Mr. W. M. Jenkins. "Modern Methods of Coal Shipment."

University of London, at King's College, Strand, W.C. 5.30 p.m. Dr. Carlo Anti, "The Italian Excavation in Cyrene."

At University College, Gower Street, W.C. 5.15 p.m. Dr. E. A. Hauser, "The Colloid Chemistry of the Rubber Industry." (Lecture VI.)

At Westfield College, Hamstead, N.W. 5.15 p.m. Prof. Dr. E. de Selincourt, "Dorothy Wordsworth."

SATURDAY, NOVEMBER 19. L.C.C. The Horniman Museum, Forest Hill, S.E. 3.30 p.m. Mr. H. N. Milligan, "Common Mistakes about Evolution."

Public Works, Roads and Transport Congress, at the Royal Agricultural Hall, Islington, N. 11 a.m. Mr. W. Weaver, (a) "Cleansing." Mr. A. L. Thomson, (b) "Yield of House Refuse."

Royal Institution, 21, Albemarle Street, W. 3 p.m. Mr. Gustav Holst, "Samuel Wesley and Robert Pearsall."

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